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NORTH AMERICAN SILURIAN RECEPTACULITID ALGAE

MATTHEW H. NITECKI

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RECEPTACULITID ALGAE

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MATTHEW H. NITECKI

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Field Museum of Natural History*

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ABSTRACT

Receptaculitaceae is considered an algal family within the order Dasycladales. The family is a coherent group that possesses anatomical characters common with the recent Dasycladales. The geographic and stratigraphic distribution of Silurian receptaculitids is along the reef belt in a narrow zone from Iowa to Newfoundland. The ecological distribution of most Silurian species is within the reef complex; a few species are found in the carbonate inter-reef facies and a few in shaly rocks.

The Silurian receptaculitids in North America are represented by three tribes, four genera, and twelve species. The tribe Cyclocriniteae is represented by *Cyclocrinites dactioloides* and *C. gregarius*; Calathieae is represented by *Calathium egerodae* n. sp.; Receptaculiteae consists of *Receptaculites* and *Ischadites*; *Receptaculites* is represented by *R. sacculus*, and *Receptaculites* sp., and *Ischadites* by *I. koenigii*, *I. stellatus*, *I. abbottae*, *I. hemisphericus*, *I. burntensis*, *I. subturbinatus*, *I. planoconvexus* n. sp., *I. prismaticus* n. sp., and *Ischadites* ? sp.



TO MY WIFE
DORIS V. NITECKI
WHO MAKES OUR GROWING OLD DELIGHTFUL

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ABBREVIATIONS

AMNH	American Museum of Natural History, New York, New York.
BMNH	British Museum (Natural History), London, Great Britain.
CAS	Chicago Academy of Sciences, Chicago, Illinois.
CGS	Canadian Geological Survey, Ottawa, Ontario.
ETT	E. T. Tonry Private Collection, Chicago, Illinois.
FMNH	Field Museum of Natural History, Chicago, Illinois.
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.
MU	Miami University, Oxford, Ohio.
NYSM	New York State Museum, Albany, New York.
OS	Orton Museum, Ohio State University, Columbus, Ohio.
PM	Peabody Museum, Yale University, New Haven, Connecticut.
PU	Princeton University, Princeton, New Jersey.
ROM	Royal Ontario Museum, Toronto, Ontario.
UCC	University of Cincinnati, Cincinnati, Ohio.
UCMP	Museum of Paleontology, University of California-Berkeley, California.
UIIC	University of Iowa, Iowa City, Iowa.
UIX	University of Illinois, Urbana, Illinois.
UMMP	University of Michigan Museum of Paleontology, Ann Arbor, Michigan.
USNM	United States National Museum, Washington, D. C.
UWM	Greene Museum, University of Wisconsin-Milwaukee, Wisconsin.

INTRODUCTION

"The plants of the Paleozoic period, though often differing considerably from those of the same class in the floras of to-day, exhibit a remarkably high type of organization . . . some are decidedly superior in the complexity of their structure, as also in size, to modern survivals of the same stock"

Seward, 1965, p. 67

This paper is a part of a larger study of the comparative biology of North American receptaculitids. The first Silurian receptaculitid in America was described and illustrated by Owen (1844) as *Lunulites* [= *Cyclocrinites*] *dactioloides* and was followed by a great number of brief descriptions of species and genera particularly by Hall and Billings in the nineteenth century. (The history of these papers is summarized in the synonymy list.) The earlier workers did not recognize the algal nature of receptaculitids, neither was the relationship of various species clearly understood.

No systematic revision of American Silurian receptaculitids is available. In the past, many receptaculitid species have been described as sponges, as an appendix to sponges or as problematic organisms. Recent work by a number of authors (Currie and Edwards, 1943; Elias, 1947; Osgood and Fischer, 1960; Kesling and Graham, 1962; Korde, 1963; Nitecki, 1967 and subsequent; Byrnes, 1968; and Rietschel, 1969) shows that most taxa of receptaculitids are green algae, and therefore a program of systematic study of receptaculitids as algae has been initiated.

Receptaculitids are a family placed in the order Dasycladales and consisting of four tribes: Amphispongieae, Cyclocriniteae, Calathieae, and Receptaculiteae. Amphispongieae and North American Cyclocriniteae have already been redescribed as algae (Nitecki, 1970a, 1971b) and the work on Calathieae is in progress (Nitecki, 1971c). Receptaculiteae are based upon two genera: *Receptaculites* and *Ischadites*. Four species of *Ischadites* have been redescribed: *koenigii*, *elrodii*, *stellatus*, and *abbottae* (Nitecki, 1969b, 1970b, 1971a, c).

The Silurian receptaculitids are common in Europe; cyclocrinitids have been monographed by Stolley (1896) and many significant papers on the genera *Receptaculites* and *Ischadites* have been pub-

lished. The most important of these are Gümbel (1876), Hinde (1884), Rauff (1892), and Rietschel (1969).

This paper describes the paleontology of North American Silurian receptaculitids as dasyclad algae. In South America, the Ordovician and Devonian receptaculitids are well documented, however, their Silurian occurrences are inadequately known (Camacho, personal communication). All tribes, except Amphispongiaeae, are present in the North American Silurian. Amphispongiaeae are found in America in Ordovician rocks, and in Europe in Silurian (Ludlow). Their absence from the Silurian strata in America may be due to the bias of collecting. The Silurian American Cyclocriniteae are represented by one genus, *Cyclocrinites*, with two closely related species, *dactiolooides* and *gregarius*. The Silurian Calathieae in North America consist of one species, *Calathium egerodae*. The tribe Receptaculiteae possesses two genera, *Receptaculites* and *Ischadites*. Silurian *Receptaculites* has one species, *sacculus*, based upon a single poorly preserved incomplete specimen and some unnamed fragments. The Silurian ischaditids are the most abundant and the most diversified group and are composed of eight species: *I. koenigii*, *I. stellatus*, *I. abbottae*, *I. hemisphericus*, *I. burntensis*, *I. subturbinatus*, *I. planoconvexus*, *I. prismaticus*, and *Ischadites* sp.

All of these species of receptaculitids are very closely related, have often been confused in the past, and possess overlapping morphological characteristics that give the family an unmistakable unity and coherence.

SPELLING AND AUTHORSHIP OF THE NAME *RECEPTACULITES*

The first receptaculitid described was the Devonian *Receptaculites neptuni* DeFrance, 1827. DeFrance (1827) spelled the name in French *Réceptaculite*, and in supposed Latin *receptacules Neptuni*. The name *Réceptaculite* remained in French literature for a long time and entry on receptaculitids in the *Grand Dictionnaire Universel du XIX^e Siecle* (Larousse, 1875, p. 772) used the term as originally spelled by DeFrance. The Latin spelling, was, however, changed by Deshayes (1828) to *Receptaculites*, the plural of the French *Réceptaculite*. Such an alteration of the name was common practice in French systematics of the period, and was not considered an emendation; Deshayes attributed the genus to DeFrance. The French title of his encyclopedia article was *Réceptaculite*, the Latin subtitle *Receptaculites*. With the few exceptions listed below, subsequent authors have used the name *Receptaculites* DeFrance. *The Nomenclator Animalium Generum et Subgenerum* (Schulze et al., 1935) and *Nomenclator Zoologicus* (Neave, 1940) erroneously attributed the name *Receptaculites* to Blainville, 1830. Although DeFrance, 1827, and Deshayes, 1828, were cited in successive editions of the French *Dictionnaire d'Histoire Naturelle*, it appears that the authors of the *Nomenclators* were unaware of the Deshayes article. Shimer and Shrock (1944, p. 57) gave the name as *Receptaculites* Blainville, 1830. Laubenfels (1955, pp. 108, 109) wrote that the name was "based on retention of *Receptaculites* Blainville, 1830, established by nearly universal usage, instead of its senior synonym *Receptacules* DeFrance, 1827." He also stated that he had submitted a case for decision to the International Commission of Zoological Nomenclature. The search of Commission publications, and subsequent direct appeal to the Commission failed to trace any application for a decision on the spelling of this name.

Wells (1956) for the first time correctly attributed the name *Receptaculites* to Deshayes, 1828, and not to Blainville, 1830. Mitecki (1967b), unaware of Wells' (1956) notice, applied to the International Commission on Zoological Nomenclature to use its plenary

powers to validate the generic name *Receptaculites* Deshayes, 1828, and to suppress the earlier name *Receptacules* Defrance, 1827. The Commission acted on the proposal in the Opinion 909. The name *Receptaculites* Deshayes, 1828, has now been placed on the official list of Generic Names, and the name *Receptacules* Defrance, 1827 is now a rejected and invalid name (China, 1970).

The genus *Receptaculites* Deshayes, 1828, is now together with all other receptaculitids transferred to the plant kingdom. According to the nomenclatural rules of the Zoological and Botanical Codes, the transfer carries with it the decision of the International Commission on Zoological Nomenclature as regards the name of Deshayes.

GEOGRAPHIC DISTRIBUTION

The distribution of Silurian receptaculitids (fig. 1) corresponds with the distribution of the Silurian reefs in North America. Receptaculitids have been collected mainly in a narrow belt extending from the state of Iowa to Newfoundland and including localities in Illinois, Wisconsin, Indiana, Ohio, Ontario, Anticosti Island, New York, and Maine. The greatest concentration of ischaditid localities is around Chicago, Illinois, and finds of cyclocrinids are common in Iowa and Ohio. All other localities have produced very few specimens. Although this distribution corresponds approximately with the Silurian reef belt it also may represent a significant bias in collecting and more sites may be discovered in the future, particularly in the Canadian Arctic. The localities in Northern Ontario in King William Land, Northwest Territories, in Maine, and in Newfoundland that produced single specimens each may represent poorly studied and poorly collected geographic areas rather than a restrictive distribution.



FIG. 1. Map of North America showing the geographic distribution of Silurian receptaculitids.

STRATIGRAPHIC DISTRIBUTION

Stratigraphic distribution of receptaculitids (fig. 2) is somewhat irregular. Wenlock and Ludlow species are abundant, but no Pridoli forms are known. However, one species (*Ischadites stellatus*) known from a few specimens from the Ludlow in the Midwest is also known from the Devonian of Ontario. Other ischaditids are also common in the Wenlock-Ludlow, and several species are common in Llandovery as well.

Cyclocrinids are represented by the Lower Silurian *Cyclocrinites gregarius* and by *C. dactiolooides* that has a wide stratigraphic range from the Llandovery through the Ludlow series. The distribution of the genus *Receptaculites* in North America is interesting. The genus is common in the Devonian in Europe and is fairly common in the Devonian of North America. However, the most abundant *Receptaculites* in North America are collected from the Ordovician, where, for example, *Receptaculites oweni* is used as an index fossil. However, the Silurian *Receptaculites* are represented only by one specimen of *R. sacculus* and a few fragments of unnamed species.

The stratigraphic position of *Calathium* is also disjunct. The genus was first based upon the specimens collected mostly from the Lower Ordovician rocks of Newfoundland. The geographic distribution of the genus has been later extended to Manchuria (Endo, 1932), to the Southwestern United States (Paige, 1916), and to the Arctic (Holtedahl, 1920). The Russian specimens described as *Soanites* (Miagkova, 1965) and some unpublished fossils from Australia also belong to Calathiidae. However, all these calathiids are Ordovician and a great stratigraphic hiatus between them and the Silurian specimens exists. It is this long span of time and the relative poverty of the fossil record that caused Toomey and Ingels (1964) to doubt the existence of Silurian calathiids. *Calathium egerodae*, common in Ludlow is also found in Wenlock, however its lower stratigraphic limit is not well known.

Extinctions and sudden appearances of various groups or organisms are not surprising when the presence of calcareous and non-calcareous forms are considered. Among some recent algae certain

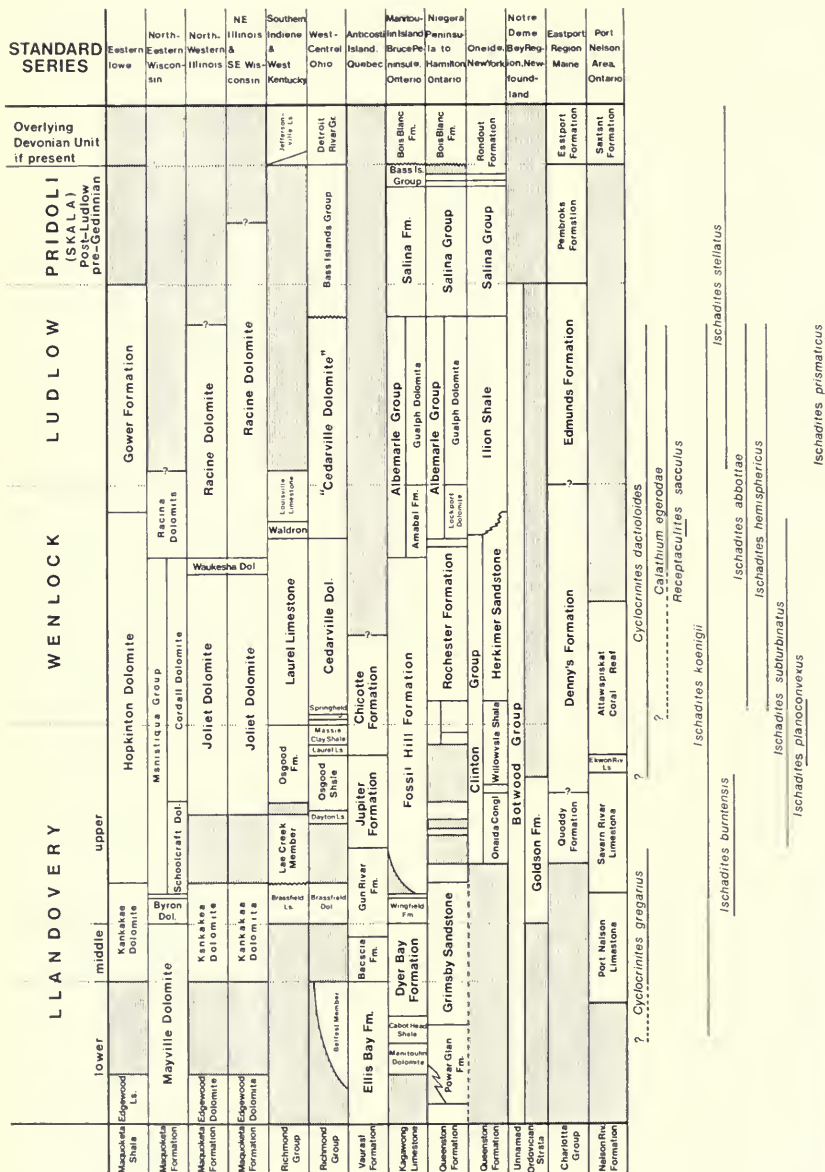


FIG. 2. Correlation chart of North American Silurian and the stratigraphic ranges of American receptaculitid species. Stratigraphic sections modified from Berry et al., 1970.

taxa possess calcareous skeletons while other related genera are non-calcareous. The degree of calcification within genera varies and different parts of thalli are differentially calcified. Thus what may appear as a major event in evolutionary history, a major radiation at any level of taxonomic organization, may in effect represent only the appearance or disappearance of minor aspects of calcification. Further, the calcification also varies during development. *Acetabularia*, a recent dasyclad alga, for the first four years of its life is non-calcareous and only becomes an encrusted plant in the fifth year when fully mature.

ALGAL NATURE OF RECEPTACULITIDS

No consensus of opinion exists as to the taxonomic placement of receptaculitids. Since Kesling and Graham (1962) suggested that these fossils are algae, a number of papers on receptaculitids have been published. Nitecki (1967 and subsequent), Byrnes (1968), and Rietschel (1969) have supported the interpretation of receptaculitids as green algae. However, Lehman (1964) considered them animals closely related to sponges. Müller (1967), who studied *Receptaculites neptuni*, found it unrelated to any known group of organisms. Huicke and Voigt (1967) considered *Mastopora*, *Coelosphaeridium*, and *Cyclocrinus* [= *Cyclocrinites*] to be algae but *Receptaculites* and *Ischadites* to be related to sponges. In 1968 Müller erected what he considered to be a new order for receptaculitids and placed them in the animal kingdom close to Porifera and Archaeocyatha. It is of interest to observe that those writers who believed receptaculitids to be animals based their conclusions mainly upon single species and did not discuss Kesling and Graham's (1962) arguments. However, supporters of the algal nature of receptaculitids also generally based their conclusions upon a limited number of taxa. Nitecki (1967 and subsequent) has argued the algal character of receptaculitids before and only additional ideas will be presented here.

There is no consensus of opinion as to what constitutes the receptaculitid complex. Byrnes (1968) included three genera in the family: *Receptaculites*, *Sphaerospongia*, and *Ischadites*, and considered *Lepidolites* Ulrich a synonym of *Ischadites*.

Rietschel (1969) divided receptaculitids into three groups as follows:

1. Group *Receptaculites* including:

Receptaculites DeFrance, 1827

Ischadites Murchison, 1839

Acanthochonia Hinde, 1884

Dictyocrinus Hall, 1859

Ehlersospongia Fagerstrom, 1961

2. Group *Sphaerospongia* including:
Sphaerospongia Pengelly, 1861
3. Group *Tettragonis* including:
Tettragonis Eichwald, 1842
Selenoides Owen, 1852
Lepidolites Ulrich, 1889
Palaeospongia Orbigny, 1849

However, Rietschel did not include the tribe Cyclocrineae [= Cyclocriniteae] in the receptaculitids.

On the other hand, Nitecki (1970a) considers *Lepidolites* a cyclocrinid, and the tribe Cyclocriniteae to be a receptaculitid group. The acceptance of cyclocrinids as receptaculitids will strengthen the argument in favor of the algal nature of receptaculitids.

The cyclocrinids are now accepted by paleontologists as dasycladaceous algae. Receptaculiteae proper are less generally accepted, and the close relationship of all Cyclocriniteae and Receptaculiteae is advocated by Nitecki (1967 and subsequent) only. Byrnes (1968) and Rietschel (1969), on the other hand, accept only *Lepidolites* as receptaculitids.

There is no doubt that Cyclocriniteae are algae, therefore, if it can be shown that there is no fundamental difference between cyclocrinids and other receptaculitid tribes then all will be algae. Accordingly, cyclocrinids are now compared with ischaditids. *Ischadites hemisphericus* is a typical ischaditid, closely related to *I. subturbinatus*, *I. abbotiae*, and *I. koenigii*. At the same time, it is strikingly similar to *Cyclocrinites dactioloides*, a typical cyclocrinid. In museum collections the specimens of these two species commonly have their names interchanged, clearly indicating the difficulties of differentiating between these two taxa, and indeed, showing that the two species are similar. Cyclocrinids in North America have, in the past, been defined mostly on the external characters and the degree of preservation, and were generally considered to belong among sponges. *I. hemisphericus* likewise, has been described and identified in the past, only from the external characters and has also been considered a sponge. Both *I. hemisphericus* and *C. dactioloides* occur close together stratigraphically and geographically, and are commonly represented by fragmentary material. They are found mostly in dolomites which tend to obscure the fine anatomical details. The thalli of poorly preserved or incomplete specimens of *I. hemisphericus* and *C. dactioloides* are indistinguishable from one another. The complete fossils of both species are also similar and

may be globular or barrel shaped. Laterals in *C. dactioloides* are seldom preserved, and therefore their distribution on the main axis is commonly deduced from the distribution of facets upon their surfaces. In *I. hemisphericus* the laterals are more often preserved. When the facets of these two groups are compared the tops of the thalli of *I. hemisphericus* are indistinguishable from the tops of thalli of *C. dactioloides*. Both have six-sided lateral heads forming the six-sided facets, a shape more common among cyclocrinitids than ischaditids. This is particularly true of tops of worn-out specimens where the surface of *I. hemisphericus* often consists of six-sided facets with small perforations in the middle, just like the preservation of facets of *C. dactioloides*. Both species appear to have laterals arranged in a tightly packed spiral. The stellate structures on top of *I. hemisphericus* are seldom preserved and in *C. dactioloides* they are absent. However, in Ordovician *Cyclocrinites darwini*, a form related to *C. dactioloides*, the stellate structures are similar to the stellate structures of *I. hemisphericus*. Preservation in both groups is similar, possibly because the nature of the enclosing rock and the nature of the depositional environments were the same. Calcification at the bases of the lateral heads is similar in both groups; however, *I. hemisphericus* is more extensively calcified and, in addition, its laterals are calcified also. The shafts of branches are seldom calcified in *C. dactioloides*.

The proposed classification of receptaculitids based upon the systematic examination of many type specimens and upon the morphological comparison with recent Dasycladales is as follows:

Order Dasycladales Pascher, 1931

family Receptaculitaceae Eichwald, 1860

tribe Amphispongiae Nitecki, 1971

genus *Amphispongia* Salter, 1861

genus *Anomaloides* Ulrich, 1878

tribe Cyclocriniteae Pia, 1920

genus *Lepidolites* Ulrich, 1879

genus *Cyclocrinites* Eichwald, 1840

tribe Calathieae Nitecki, 1969

genus *Calathium* Billings, 1865

genus *Calathella* Rauff, 1894

tribe Receptaculiteae Nitecki, 1969

genus *Receptaculites* Deshayes, 1828

genus *Ischadites* Murchison, 1839

genus *Sphaerospongia* Pengelly, 1861

MORPHOLOGY

MORPHOLOGIC CHARACTERS USED IN THE STUDY OF RECEPTACULITIDS

There is uncertainty, of course, regarding what constitutes the best characters to be used in a taxonomic study. It is impossible to adopt one single character that could be of equal weight for all species of receptaculitids. Almost every character used is subject to great variation and few characters can be considered as satisfactory for differentiation of individual species and genera. But certain characters are less variable in one group than in another and thus an attempt to show which characters are less and which are more variable within the taxon should be made. In receptaculitids, as in other fossils, in addition to the geographic and ecological distribution the stratigraphic distribution is also important. Thus, for example, the variation in shape of lateral branches in *Ischadites* may be considerably different from one stratigraphic locality to another.

The measurements of sizes of thalli and of individual anatomical elements are of limited practical value in systematics. This is particularly true since size varies with age. In addition, most specimens are incomplete and, therefore, what is measured is fragmentary. An attempt was made to evaluate ratios of measurements, for example, the height and width, but these were of no help and cannot shed light even upon the possible environmental conditions.

The characters used in the present study vary from the higher taxonomic units to lower. Thus for the separation of the family Receptaculitaceae from the family Dasycladaceae the arrangement of laterals upon main axis are used. More characters are used for the separation of tribes within Receptaculitaceae and these include, in addition to the arrangement of laterals, the complexity of branches, the degree of calcification, and the presence or absence of rhizoidal attachment. The genera and species are differentiated on the most variable characters. These are mainly the shape of thalli, the shape of facets, and the details of the anatomy of lateral heads.

In the past, when one or a few fossils were studied at any one time and when such studies were conducted at intervals of time, and

no comparisons were made of preservation and other factors, each specimen was often a new species. When large collections are made or are available for examination, the variabilities of individuals and groups of individuals become clearer and hence the number of taxa are reduced. However, new taxa are still described but hopefully only after comparisons with other species are made. It is extremely difficult to arrive at a clear concept of species in this group of organisms. It would be of great help to have at least two characters that could be used to differentiate species. But, unfortunately, this is not always possible, and often only one character is of great significance.

Rauff (1892) reconstructed the growth pattern of receptaculitids from the distribution of facets upon the thallus. Pia (1927) and Nitecki (1970a) interpreted the arrangement of laterals upon the main axis also from the external morphology. For Rietschel (1969) the external morphology was also the key to the arrangement of laterals and to the orientation of the thallus. However, the external morphology, mainly the distribution of facets, is often independent of the arrangement of branches upon the central axis. In recent dasycladales, *Neomeris dumetosa* and *Bornetella oligospora*, the irregular distribution of cortical facets does not correspond at all with the regular whorled arrangement of branches. In receptaculitids the arrangement of branches and the growth pattern can be reconstructed only from the actual position of branches upon the main axis. The beautiful sinusoidal lines upon the surface of the thallus, so fascinating to paleontologists, do not reflect the position of branches upon the axis nor their growth, but are caused by the packing of heads upon the surface.

THALLUS

The shapes of thalli of North American receptaculitids are globular, conical, or irregular (fig. 3). Globular shapes are the most common and these may be ovoid (*Ischadites stellatus*, *I. koenigii*, and *Receptaculites sacculus*), barrel shaped (*Ischadites abbottae* and *I. hemisphericus*), spheroid (*Cyclocrinites dactioloides* and *C. gregarius*), slightly flattened (*Ischadites subturbinatus*), or much flattened discs (*Ischadites planoconvexus*). The conical shapes are found among *Calathium egerodae*, and some of the most irregular shapes are found among *Ischadites koenigii* (fig. 4).

In addition to the general body shape, certain receptaculitids can be differentiated by presence or absence of a twist of the thallus.

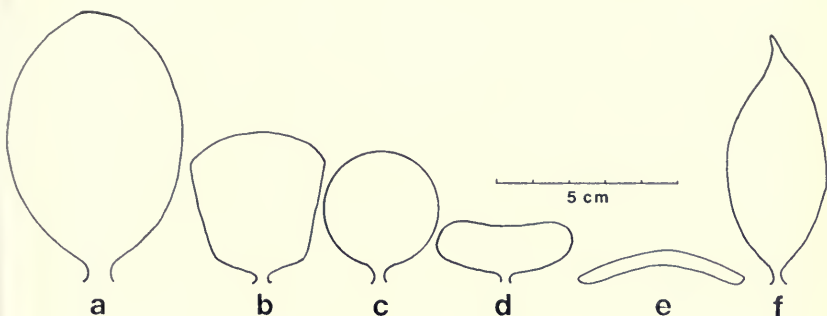


FIG. 3. Shapes of thalli of six American Silurian receptaculitids. a, ovoid (*Ischadites koenigii*, FMNH 17674); b, barrel shape (*Ischadites hemisphericus*, FMNH UC 10817); c, spherical (*Cyclocrinites dactioloides*, FMNH P5750); d, slightly flattened (*Ischadites subturbatus*, FMNH UC 56339); e, much flattened (*Ischadites planoconvexus*, NYSM E3378); and f, conical (*Calathium egerodae*, FMNH PP 17549).

Thus most Silurian receptaculitids do not show any noticeable body twist. However, most *Ischadites koenigii* and a few *Calathium egerodae* exhibit a twist of their bodies (fig. 5). Non-Silurian representatives of these genera may or may not have a twisted thallus.

The North American Silurian receptaculitids are much smaller in size than their Ordovician and Devonian relatives. The largest receptaculitids are the Ordovician *Receptaculites oweni*; the adult form was well over 30 cm. in diameter. The Lower Ordovician calathitids may have been equally long. The Devonian *Receptaculites* did not quite attain such large size; however, they are larger than any known Silurian form.

No actual distinct attachment rhizoid is observed in Silurian receptaculitids which differ from the Ordovician species where good rhizoids are observed. Nonetheless, by analogy with Ordovician fossils, some attachment rhizoid must have been present. The attachment scars, however, are observed (fig. 6).

SHAPE OF THALLUS AS CRITERION OF RECEPTACULITID SPECIES

The delineation of species in fossils, particularly in invertebrate animals and "lower" plants, is generally vague. Although an attempt is often made to define a species of fossil organisms in terms of a living population, the results are mostly descriptions of individual specimens. This undesirable practice is forced upon paleontology by nature of preservation of the fossil material and often by the limited number of organisms available for study.

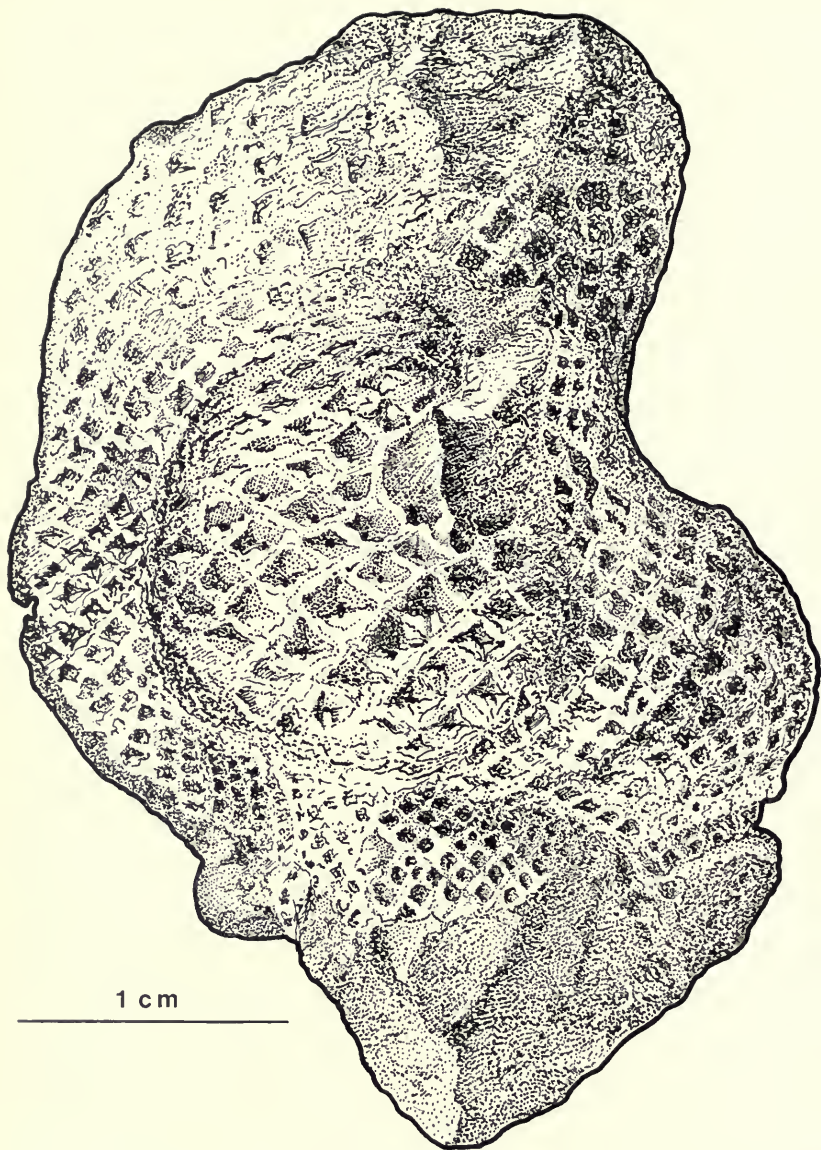


FIG. 4. The irregular shape of the thallus of *Ischadites koenigii*, FMNH PP 17668.

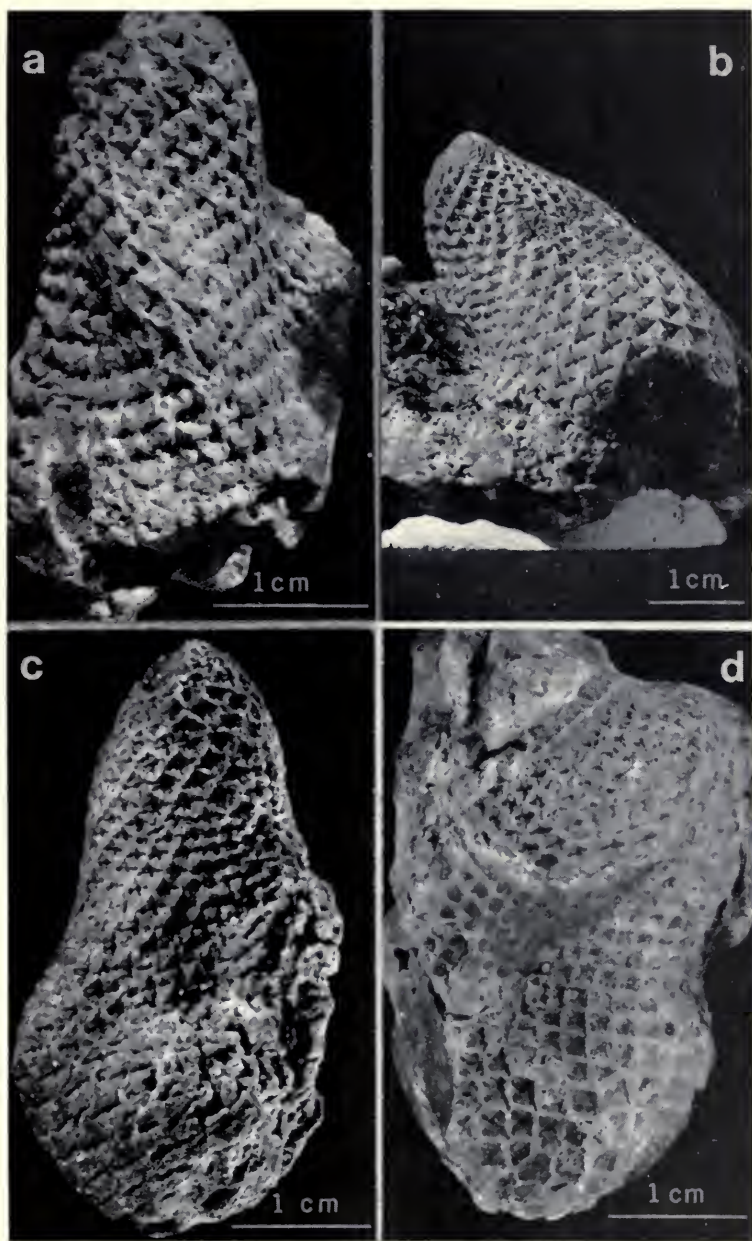


FIG. 5. Five thalli of *Ischadites koenigii* from Chicago, Illinois, showing a twist of the thallus. a, spiral arrangement of laterals FMNH PP 17659; b, FMNH PP 17671; c, FMNH PP 17639; d, FMNH PP 17668. (b and c after Nitecki, 1939, figs. 9A, F.)



FIG. 6. Attachment scar of *Ischadites subturbinatus* FMNH P 16079. The smaller laterals of the upper part of this thallus are shown in Figure 7.

In the study of receptaculitids the problem of preservation is serious and species are based almost exclusively upon morphology seen in a few specimens. In addition, in most cases the specimens are often only partially preserved, and among North American ischaditids general preservation is that of molds. In the past when receptaculitids were considered sponges, species were differentiated on the basis of differences of "spicules." This is to a great extent followed in the present paper; however the "spicules" are now interpreted as the lateral branches. The greatest difficulty is that of preservation. Externally most specimens of receptaculitid species are alike, and often, for example, the exterior of cyclocrinitids cannot be differentiated from that of ischaditids. Certain American Ordovician and Silurian species of *Ischadites* cannot be separated by the exterior of the thallus only. Yet, often, only the general body shape is preserved, and the elements of lateral branches may show little differentiation. Thus the shape of the thallus may sometimes be the only differentiating criterion available.

The thalli of ischaditids generally are globular, varying from ovoid to barrel shapes. Only one species, *Ischadites koenigii*, shows great variations of body shape; however, most other species exhibit some uniformity in the shape of the thallus. Thus the species must also be differentiated on the basis of the internal anatomy, the shape of laterals, differentiation of laterals, and the complexities of stellate structures.

Ischadites subturbinatus and *I. planoconvexus* are the only American species with thalli that are flattened spheroid oblates or doughnut-shaped. The question is whether these organisms should be differentiated on the basis of body shape alone, particularly since the shape could reflect ecological adaptations or compressions after death. Among cyclocrinitids there are shapes that appear ecologically controlled, and the subtorous bodies have been interpreted as a sitting-down adaptation (Nitecki, 1970a). Among a few ischaditids there appears to be a post-mortem compression and fossi's distinctly flattened perpendicularly to the main axis are found. However, not all *Ischadites subturbinatus* from Waldron, Indiana, are subtorous and although some compression should be expected in the shaly matrix, the lateral flattening is sometimes absent.

Among recent Dasycladales the species of *Bornetella* are differentiated on the basis of the morphology of gametangia and gametangial cysts. Nevertheless, some species of *Bornetella* can be differentiated also by their body shapes. Thus *Bornetella sphaerica*, although distinct in the spherical shape of gametangia, also has a spherical thallus (Egerod, 1952). It seems therefore reasonable to accept the original description of *Ischadites subturbinatus* based upon the shape of the body as valid and to differentiate this species together with *I. planoconvexus* on the basis of their body shape. However, in other species caution needs to be exercised because gradations in shapes are found.

MAIN AXIS

The existence of the receptaculitid main axis has been demonstrated already and the central axis has been illustrated (Nitecki, 1969c, 1970a, 1971a). The shape of main axis differs as much as does the shape of the thallus. Thus in cyclocrinitids and in ischaditids the main axis in most plants was apically bulbous. In calathiids the main axis was pointed, and among the genus *Receptaculites* the main axis may have been a large central vacuole filled with sap in the manner of modern *Cymopolia*. In receptaculitids the main axis was



FIG. 7. Close-packed upper laterals of *Ischadites subturbinatus* showing the apparent arrangement in whorls. FMNH P 16079. The lower larger laterals are shown in Figure 6.

probably a continuous central vacuole filled with sap, in the manner of recent Dasycladales. While the main axis was straight in most species, it was twisted in *I. koenigii* and in a few specimens of *C. egerodae*.

LATERALS

In all Cyclocriniteae and Receptaculiteae the laterals are arranged in a spiral. However, the spiral is packed so closely that laterals appear to have been borne in a whorl (fig. 7). For this reason the arrangement of laterals in the spiral has not been recognized in the past (Nitecki, 1969b). In Calathieae (and in Amphispongieae) the laterals are distinctly in whorls. Thus the family Receptaculitaceae is characterized by both the spiral and whorled arrangement of laterals. Among fossil and recent Dasycladaceae the laterals are arranged in whorls only.

The anatomy of laterals within receptaculitids varies little, and among the Silurian North American members all laterals are primaries only (fig. 8). Generally the branches within single organisms

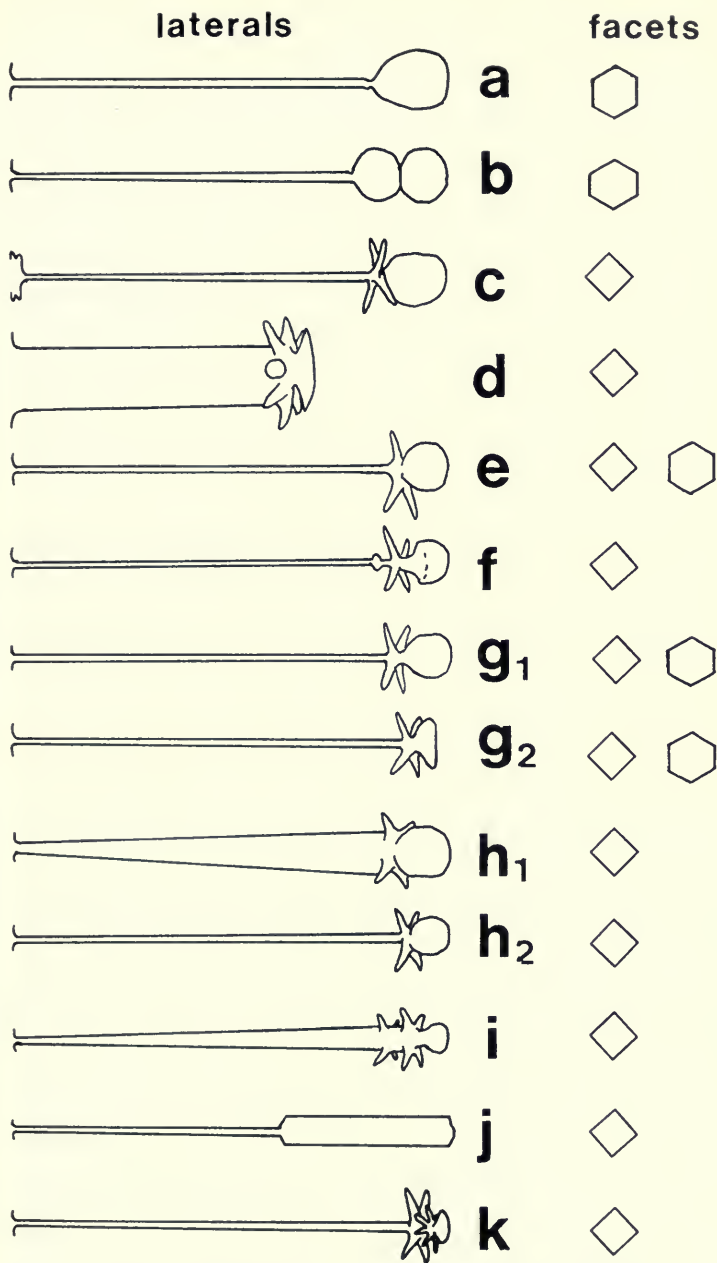


FIG. 8. Laterals and facets of Silurian receptaculitids. **a**, *Cyclocrinites gr. parius*; **b**, *Cyclocrinites dactioloideus*; **c**, *Calathium egerodae*; **d**, *Receptaculites saeculus* (partly reconstructed); **e**, *Ischadites koenigii*, planoconvex; **f**, *I. subumbinatus*; **g**, *I. hemisphericus*; **h**, *I. abbottae*; **i**, *I. burntensis*; **j**, *I. prismaticus*; **k**, *I. stellatus*. Not to scale.

show variation only in size and the largest laterals are found somewhat above the midpoint. The simplest laterals are found among cyclocrinitids. In the Silurian cyclocrinitids stellate structures are absent but in certain Ordovician cyclocrinitids four or more ribs of stellate structures are present. The branch of *Cyclocrinites gregarius* consists of a shaft and a single head (fig. 8a). The branch of *C. dactiolooides* consists of a shaft and a double head (fig. 8b). The branches of various species of *Ischadites* are more diversified. The laterals of *I. koenigii*, *I. hemisphericus*, *I. subturbinatus*, and *I. planoconvexus* possess similar lateral heads (fig. 8e-g). The stellate structures in these generally consist of four ribs, often fewer, and the heads are generally small. The so-called "plates" of earlier workers are upper, flatter parts of heads. These heads are often thin. In *I. abbottae* the upper laterals are conical and gradually expanding (fig. 8h₁); in *I. hemisphericus* there are two sets of stellate structures; in *I. prismaticus* the laterals are modified into a rectangular ray (fig. 8j). In *I. stellatus* the heads consist of two sets of stellate structures, one above another, and are composed of four and eight ribs each (fig. 8k). The lateral of *I. burntensis* (fig. 8i) consists of expanding shaft and of a double set of stellate structures. Thus the branch is similar to the expanding branch of *I. abbottae* and to the double set of stellate ribs of *I. stellatus*.

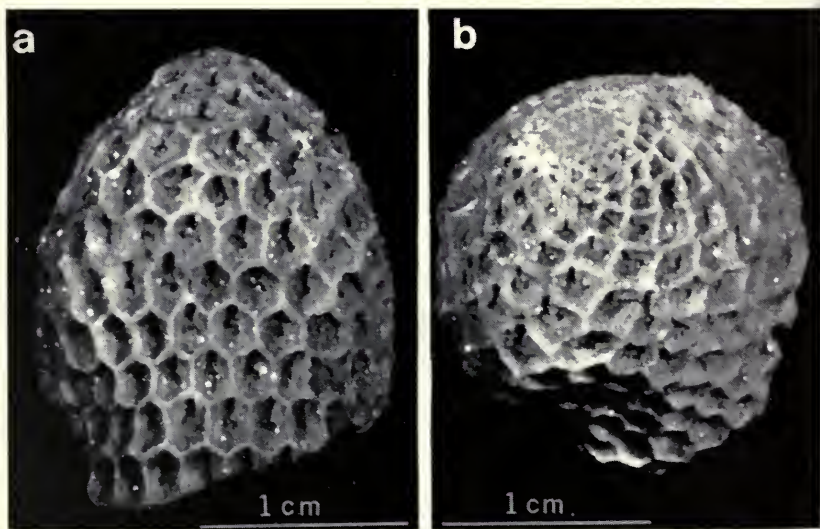


FIG. 9. Faceted surface of a single specimen of *Ischadites koenigii*. FMNH PP 17641. a, six-sided facet; b, four-sided facet.

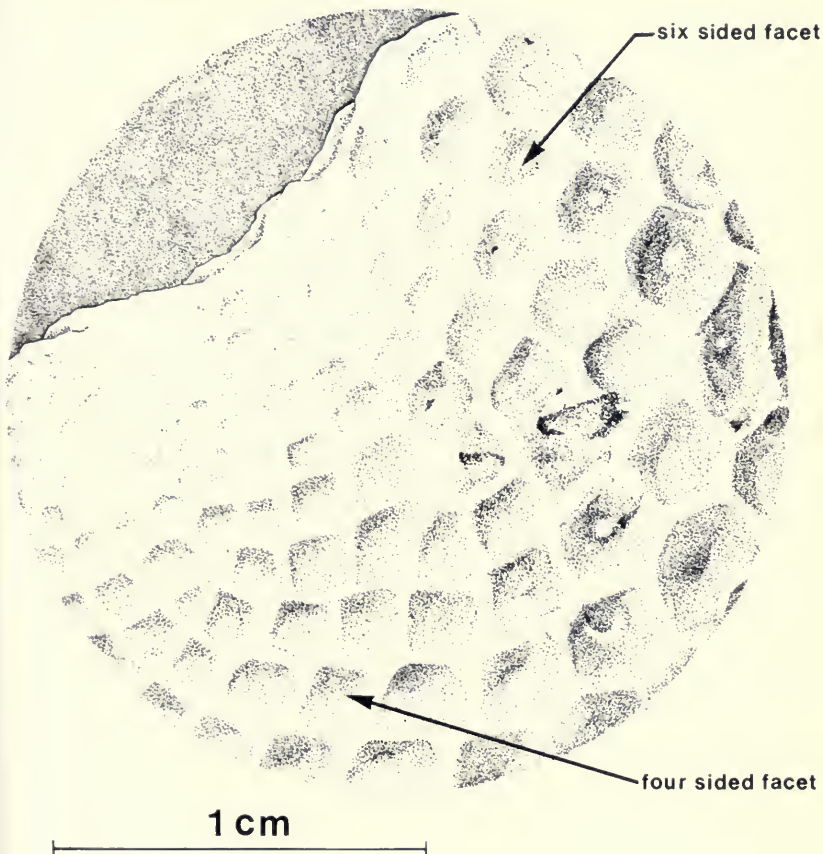


FIG. 10. The four- and six-sided facets of *Ischadites hemisphericus* found on one thallus. FMNH PP 17425.

The laterals of calathiids are similar to the laterals of ischaditids, however, the calcification differs; in calathiids it forms an almost continuous envelope around the main axis, and thus the base of calathiid laterals often has a pronounced proximal enlargement (fig. 8c). The laterals of *Receptaculites* are short and thick (fig. 8d), and in some Ordovician forms complicated stellate structures form. The stout nature of the lateral of *Receptaculites* sets it apart from all receptaculitids.

FACETS

The commonest shapes of facets of Silurian receptaculitids are hexagons or rhombs. The six-sided facets are generally regular hex-

agons, the four-sided are generally regular rhombs or rarely squares. The five and seven-sided facets are found but they are rare. In certain species the facets are almost exclusively hexagons (*Cyclocrinites dactiolooides* and *C. gregarius*), in other are mostly rhombs (*Ischadites abbottae*, *stellatus*, *planoconvexus*, *Calathium egerodae*, and *Receptaculites sacculus*). Among certain species both rhombs and hexagons are found together on a single thallus (*Ischadites koenigii* (fig. 9), *prismaticus*, *hemisphericus* (fig. 10), and *subturbيناتus*). When only the exterior of the plant is preserved and only the shapes of facets are noted, many of these species are easily confused.

The exact nature of factors controlling the shape of facets is unknown. However, when laterals are arranged in horizontal lines and when they alternate, then each lateral is in contact with six other laterals and the compressed heads form the hexagons. The compression is caused by the growth of heads. When heads are arranged in an unalternating pattern, the four-sided figures can form, which when compressed may form rhombs. The formation of facets may proceed also along the elements of stellate structures. The facets then form below the outer part of heads (plates) and are caused by the precipitation of carbonate between the ribs of stellate structures. The stellate structures are most commonly four-ribbed and thus the most common shape of facet is also four-sided. It is possible however that the process of formation of facets is even more complicated.

CALCIFICATION AND PRESERVATION

The degree of calcification is possibly the main factor responsible for the degree of preservation of the anatomy of receptaculitids. However, it is the preserved anatomical parts that inform us of the extent of calcification. The degree of calcification of different species and of different parts of thalli often varies. Among cyclocrinitids the most calcified is the base of the lateral head and, therefore, the resulting common preservation is that of "cups" of many authors. Sometimes the distal part of the lateral shaft is also calcified. In calathiids the lateral head, the shaft of the lateral and the main axis are calcified and a two-walled structure forms. However, the stellate structures are generally less calcified than in other members of receptaculitids.

In *Receptaculites sacculus* the short stout laterals are the most heavily calcified part of the body, and the calcification of heads

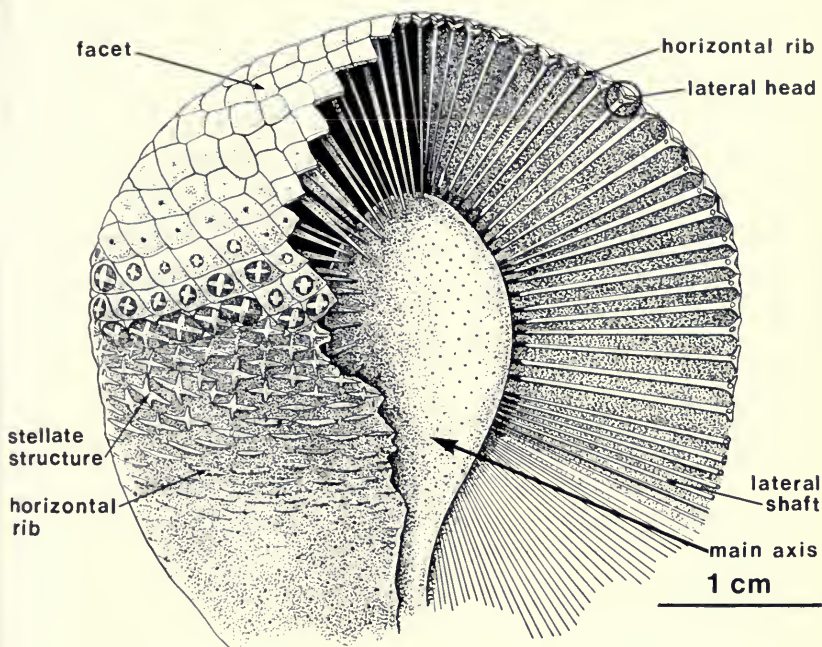


FIG. 11. Schematic representation of the gradual effects of weathering upon the ischaditid thallus. Upper parts of thallus are undamaged, in the lowermost part only the cross-section of lateral shafts are observed.

appears not to have been continuous with the calcification of the lateral shaft and, therefore, only laterals are now preserved. Little calcification of stellate structures is present in *Receptaculites sacculus*.

In *Ischadites* the stellate structures, almost always present, are the most calcified elements of the skeleton. Occasionally the lateral shaft, the lateral head, and, in some instances, the main axis are calcified.

Receptaculitids are mostly preserved incomplete as molds. In the past the poor preservation was responsible for the misunderstanding of the nature of these organisms and, as a result, the taxonomy of receptaculitids was incompletely known. It appears that the preservation is the most confusing aspect of receptaculitid studies. When only molds of laterals are known, the species and even genera cannot be easily differentiated. Therefore, in many collections Silurian *Ischadites* are confused with Ordovician *Receptaculites*, and *I. hemisphericus* is confused with *Cyclocrinites dactiolooides*. This confusion is further emphasized when only flattened-out fragments are studied.

In general, the well-preserved and complete fossils are rare in most collections and in most collecting localities. Most of the species redescribed here are known only from molds. Few morphological calcareous parts have been observed other than "negatives" of actual anatomical structures. Generally the lowermost parts of thallus are missing. Many examined specimens are dolomitic. The various degrees of weathering are shown in Figure 11, where the details of lateral heads are shown progressively exposed. Such weathering effects, caused by many processes, are very common occurrences.

PALEOECOLOGY

The characteristics most important to the understanding of receptaculitid paleoecology are: the nature of the fossil assemblage, the preservation of this assemblage, the analysis of the particular composition, and the comparisons with the recent counterparts of known ecologic nature. In addition, the interpretation of the broad elements of paleogeography and the detailed study of the lithology of the rocks is needed. Only when such studies are completed can a meaningful picture of the paleoecology emerge. It is impractical within the limitations of the present primarily morphologic and systematic study to describe extensively the ecology of the Silurian receptaculitids.

The most striking element of the ecology of receptaculitids is the association of certain species with the coral reef, and the adaptability of other species to the reef and non-reef environment (table 1). Furthermore, there are species that are found only in the mud environment. *Ischadites prismaticus* and *I. stellatus* are exclusively reef inhabitants. It appears that many of these were exposed to the high energy environment of wave and tide action. Many, of course,

TABLE 1. Ecological distribution of North American Silurian receptaculitids.

Reefs only
<i>Ischadites stellatus</i>
<i>I. prismaticus</i>
Reefs and non-reef carbonates
<i>Cyclocrinites dactioloides</i>
<i>Calathium egerodae</i>
<i>Ischadites koenigii</i>
<i>I. abbotiae</i>
<i>I. hemisphericus</i>
Pure and impure carbonates
<i>Cyclocrinites gregarius</i>
<i>Receptaculites sacculus</i>
<i>Ischadites subturbinatus</i>
Predominantly non-carbonates
<i>Ischadites burntensis</i>
<i>I. planoconvexus</i>

could have grown in protected niches of the reef. The morphology of *Calathium egerodae* (found predominantly on top of reef but rarely also in the inter-reef regimen), seems to indicate that its great morphologic variation may be due to the environment.

The *Cyclocrinites dactioloides*, *Ischadites koenigii*, *I. hemisphericus*, *I. abbottae*, and *Calathium egerodae* are found on the reef, in the reef flanks, in apparently deeper water of the inter-reef facies, many miles away from any reef structure. *Ischadites koenigii* from the top of the reef is morphologically most varied, and thus probably most exposed to the action of water.

Most fossils from the Illinois and Wisconsin regions are found on tops of reefs, and their ecology is the same as that of *I. stellatus* (Nitecki, 1971c). It is assumed that the fossils from Ohio were likewise from similar environments. It is possible that the apparently "rough-water" regimen was responsible for the preservation only of upper parts of thalli, characteristic of so many fossils of *I. hemisphericus*.

The species that have never been observed in the reef are *Cyclocrinites gregarius*, *Ischadites burntensis*, *I. subturbinatus*, *I. planoconvexus* and *Receptaculites sacculus*. Of these *I. burntensis* and *I. planoconvexus* are restricted to the shaly environments only. The Waldron Shale forms (*I. subturbinatus* and *R. sacculus*) do not show much sedimentary compression, but *I. planoconvexus*, a highly flattened Willowvale Shale form, may possibly represent the post-mortem flattening. The other non-reef species, *Cyclocrinites gregarius* and *Ischadites subturbinatus*, are found in lime and in impure lime rocks.

Thus of all known North American Silurian receptaculitids only two species are found exclusively in the reefs. Five species are both reef and non-reef dwellers and five are non-reef only (of which three are pure or impure carbonates). The associated fossil invertebrates are always "typical" of the environment. That means the reef-dwelling receptaculitids are associated with corals, bryozoans, and a few shelly forms. The associated invertebrates from the shale members are also "typical," chiefly brachiopods.

The recent members of the family Dasycladaceae are mostly tropical and mostly associated with carbonate facies and warm shallow waters. *Dasycladus clavaeformis*, however, lives half submerged in fine-grained sediments of mixed composition. *Dasycladus vermicularis* is generally found in reefs or in tide pools, and, although

it is frequent near low-tide level, it also dwells at depths down to 50 m. and is often found covered with drifted sands. The marine *Batophora oerstedii* is also found in fresh water and in brackish lakes 500 miles away from the sea. *Neomeris annulata* is found associated with reef tops, reef flanks, and in the inter-reef facies attached to shell fragments. Certain species of *Acetabularia* need sheltered, shallow, protected, niches in reefs or tidal pools, while other species can live in mangrove swamps. Thus although Dasycladaceae are, in general, indicators of tropical, warm, shallow seas, general exceptions are known.

KEY TO THE SILURIAN RECEPTACULITIDS

This key is intended not only as an aid in identifying the North American species of receptaculitids but also as a summary of taxonomic characters. The characters used are, however, not applicable to all receptaculitids. For example, stellate structures, absent in Silurian cyclocrinitids are present in Ordovician forms.

KEY TO THE SILURIAN GENERA

- | | |
|--|-------------------------|
| 1. Laterals in whorls | <i>Calathium</i> . |
| 1. Laterals in spiral | 2 |
| 2. Stellate structures absent | <i>Cyclocrinites</i> . |
| 2. Stellate structures present | 3 |
| 3. Laterals short and thick | <i>Receptaculites</i> . |
| 3. Laterals long and thin | <i>Ischadites</i> . |

KEY TO THE SILURIAN SPECIES

Receptaculites is represented by a single species, *sacculus*, and by some fragmentary material only.

Calathium is represented by a single species, *egerodae*.

Cyclocrinites is represented by two closely related species, *dactiolooides* and *gregarius*; *dactiolooides* has two and *gregarius* has one lateral head.

KEY TO THE SPECIES OF *Ischadites*

- | | |
|---|------------------------|
| 1. Stellate structures single | 2 |
| 1. Stellate structures double | 3 |
| 2. Laterals expand gradually | <i>abbottae</i> . |
| 2. Laterals prismatic | <i>prismaticus</i> . |
| 2. Lateral heads expand rapidly | 4 |
| 3. Lateral heads form rapidly | <i>stellatus</i> . |
| 3. Laterals expand gradually | <i>burntensis</i> . |
| 4. Main axis in spiral | 5 |
| 4. Main axis not in spiral | 6 |
| 5. Lower laterals fused | <i>hemisphericus</i> . |
| 5. Lower laterals not fused | <i>koenigii</i> . |
| 6. Thallus somewhat flattened | <i>subturbatus</i> . |
| 6. Thallus much flattened | <i>planoconvexus</i> . |

SYSTEMATICS

Order Dasycladales Pascher, 1931

Definition.—Thallus radially symmetrical, nonseptate, generally calcareous; main axis generally undivided and erect; branches in whorls or in tightly packed spiral; laterals initiate at apex; attachment basal; vegetative stages uninucleate, sexual stages multinucleate; reproduction sexual; gametangia positioned on branches; biflagellate isogametes present; two families; Precambrian to Recent.

Discussion.—The order has been well defined by Egerod (1952), who together with other workers recognized only one family Dasycladaceae Hauck, 1884. In the present study the second family Receptaculitaceae Eichwald, 1860 is recognized.

Family Receptaculitaceae Eichwald, 1860

Definition.—Marine algae; thallus generally globose, rarely constricted; main axis generally globose, rarely branched; primary branches tightly packed in spiral or occasionally in many whorls; secondary branches rare; cortex of four to eight-sided polygons; calcification externally heavy; little diversity of external morphology; uniformity in calcification and preservation; attachment when known anastomizing or pedicle; four tribes; ?Cambro-Ordovician to Permian-Carboniferous.

Discussion.—Nitecki (1969c) concluded that receptaculitids consist of three tribes within the family Dasycladaceae. At that time he was not able to compare the fossils in great detail with the recent representatives of the family. Nitecki (1971b) erected a fourth tribe Amphispongieae and later (1971a) considered receptaculitids as a second family within Dasycladales. The Receptaculitaceae consist of four tribes of which three are present in the American Silurian.

The record of receptaculitids is excellent from Lower Ordovician to the Middle Devonian. The uppermost Cambrian occurrences may or may not be accurate and are being presently investigated. I am unable to comment on the Permian *Sphaerospongia permotessel-*

lata from Sicily (Parona, 1933), but its high stratigraphic occurrence certainly requires further examination.

Tribe Cyclocriniteae Pia, 1920

Definition.—Thallus relatively small, globose; main axis unbranched, apically inflated; laterals in spiral, rarely branched; lateral heads commonly inflated; stellate structures when present weakly calcified; facets generally six-sided; heavy precipitation of carbonate around lateral heads. Ordovician to Carboniferous.

Discussion.—Pia (1927) included two subtribes, Cyclocrininae and Mastoporinae, in the tribe Cyclocriniteae. In Mastoporinae, Pia included *Mastopora* Eichwald, *Apidium* Stolley, and *Epimastopora* Pia. Nitecki (1970a) has stated that *Epimastopora* Pia is unknown from North America. However, Pennsylvanian fossils have been described from Kansas as three species of *Epimastopora* (Johnson, 1946, 1963). The descriptions and illustrations of these indicate highly fragmentary remains that are difficult to assign taxonomically. If these fossils will indeed prove to be *Epimastopora* and if *Epimastopora* is related to *Cyclocrinites*, then the stratigraphic range of cyclocrinitids in North America will be extended to the Pennsylvanian. The American representatives of the tribe have been extensively revised by Nitecki, 1970a, who included in the tribe Cyclocriniteae the genus *Cyclocrinites* Eichwald, 1840, *Anomaloides* Ulrich, 1878, and *Lepidolites* Ulrich, 1879. Later the genus *Anomaloides* has been removed from this taxon and placed together with *Amphispongia* in the tribe *Amphispongiae* (Nitecki, 1971b).

Cyclocrinites¹ Eichwald, 1840

Definition.—Thallus spherical, claviform, pyriform or irregular; attachment pedicle, or non-preserved; laterals regularly packed, generally unbranched; lateral heads globular, sometimes double; stellate structures rarely preserved; facets generally six-sided. Ordovician and Silurian.

Type species.—*Cyclocrinites spaskii* Eichwald, 1840.

Discussion.—North American *Cyclocrinites* are represented by eight species, two of which, *C. dactioloides* and *C. gregarius*, are

¹ Synonymy lists are given for species only. Non-American references to American species are selective and no completeness is claimed.

Silurian. *C. welleri* is the only cyclocrinitid species with branched laterals. *C. dactiolooides* is the only cyclocrinitid with a double lateral head.

Cyclocrinites dactiolooides¹ (Owen, 1844). Figures 8b, 12.

Cerionites Calvin, 1898, Iowa Geol. Surv., 8, p. 150; Calvin and Bain, 1900, Iowa Geol. Surv., 10, pp. 445, 454, 455, 456, 459; Greacen and Ball, 1944, Trans. Wisc. Acad. Sci., 36, p. 418; Lowenstam, 1957, Geol. Soc. Amer. Mem. 67, pp. 241, 245; Brown and Whitlow, 1960, U.S. Geol. Surv. Bull. 1123-A, p. 33.

Cerionites dactiolooides Meek and Worthen, 1868, Geol. Surv. Ill., 3, pp. 345-346, pl. 5, figs. 2a-c; Whitfield, 1883, Wisc. Geol. Surv., 4, pp. 267-269, 350, pl. 13, figs. 1-3; Miller, 1889, N. Amer. Geol. Palaeontol., p. 156, text-fig. 97; Calvin, 1893, Amer. Geol., 12, pp. 53-57, text-fig.; Calvin, 1893, Proc. Iowa Acad. Sci., 1, pt. 3, pp. 13-15, text-fig.; Winchell and Schuchert, 1895, Geol. Minn., 3, pt. 1, pp. 60, 67; Head, 1895, Palaeoz. sponges, p. 6; Wilson, 1895, Amer. Geol., 16, pp. 278, 279; Calvin, 1898, Iowa Geol. Surv., 8, p. 149; Whitfield, 1899, Ann. N.Y. Acad. Sci., 12, no. 8, p. 145; Calvin and Bain, 1900, Iowa Geol. Surv., 10, p. 154; Bassler, 1915, Bull. U.S. Nat. Mus. 92, p. 204; Thomas, 1923, Proc. Iowa Acad. Sci., 29, p. 85; Howell, 1943, Wagner Free Inst. Sci. Bull., 18, no. 4, pp. 35, 39-41, figs. 4, 8, 9; Ball and Greacen, 1946, Chgo. Acad. Sci., Sp. Publ. 7, p. 15; Greacen and Ball, 1946, Greene Memor. Mus., p. 11; Peck and McFarland, 1954, Jour. Paleontol., 28, no. 3, p. 298; Laubenfels, 1955, Treatise Inv. Paleontol., p. 110.

Ceryonites dactyloides Whitfield, 1882 [1883], Geol. Wisc., 4, part 3, p. 350; Whitfield, 1883, Geol. Wisc., 1, p. 362.

Cyclocrinites dactiolooides Nitecki, 1969, Fieldiana: Geol., 16, no. 14, fig. 8C; Nitecki, 1970, Fieldiana: Geol., 21, pp. 3, 4, 5, 8, 10, 18, 32, 50, 52, 74, 75, 78, 88, 93, 98-110, 134, 148, 155-156, 165, 167, 168, 171, 172, 174, 175, 177, 180, 182, text-figs. 3E, 7E, 9, 10, 18, 21A, 29, 42-45.

Cyclocrinus billingsi Pia, 1927, Hand. Paläobot., p. 66; Johnson, 1952, Colo. School Mines Quart., 47, no. 2, p. 40.

Cyclocrinus dactiolooides Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, p. 279, figs. 30, 31; Pia, 1927, Hand. Paläobot., p. 66.

Cyclocrinus (Nidulites) favus Nicholson and Lydekker, 1889, Man. Palaeontol., 1, fig. 73i.

Cyclocrinus (Pasceolus) billingsi Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, p. 215.

Cyclocrinus (Pasceolus) dactiolooides Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, p. 215.

Lunulites dactiolooides Owen, 1844, Geol. Rept. Iowa, p. 69, [406], pl. 13, fig. 4; Meek and Worthen, 1868, Geol. Surv. Ill., 3, pp. 345, 346; Miller, 1874, Cincinnati Quart. Jour. Sci., 1, no. 1, p. 5; Kayser, 1875, Z. Deut. Geol.

¹ *C. dactiolooides* has been spelled in the following ways: *dactylioides*, *dactyloides*, *dactiloides*, *dactyloides*. In this synonymy list the different spellings are not recognized.

- Gess., 27, p. 780; Miller, 1877, Amer. Palaeoz. fossils, p. 43; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 846; Miller, 1889, N. Amer. Geol. Palaeontol., p. 161; Calvin, 1893, Amer. Geol., 12, p. 54; Calvin, 1893, Proc. Iowa Acad. Sci., 1, pt. 3, p. 13; Head, 1895, Palaeoz. sponges, p. 6.
- Mastopora fava* Currie and Edwards, 1943, Quart. Jour. Geol. Soc. London, 98, pp. 235, 237-238, 239, pl. 11, figs. 1-3; Johnson, 1952, Quart. Colo. School Mines, 47, no. 2, p. 44; Johnson and Konishi, 1959, Quart. Colo. School Mines, 54, no. 1, pp. 13, 14, 15, 26, 46, 51, pl. 6, figs. 1-4.
- Mastopora favosa* Osgood and Fischer, 1960, Jour. Paleontol., 34, pp. 896, 897, 899, 901.
- Mastopora farus* Anonymous, Brit. Palaeoz. fossils, p. 38, pl. 15, fig. 9.
- Nidulites favius* Salter, 1851, Quart. Jour. Geol. Soc. London, 7, p. 174, pl. 9, figs. 16-17; Murchison, 1854, Siluria, p. 178, figs. 14 (3); Murchison, 1859, Siluria, pp. 203, 228, 542, figs. 27(3); Bigsby, 1868, Thesaurus Sil., p. 4; Murchison, 1872, Siluria, pp. 188, 208, 509, text-figs. 30(3); Salter, 1873, Cat. Camb. Sil., p. 72, figs.; Nicholson and Etheridge, 1878, Monogr. Sil. fossils, Girvan, pp. 11-13, 18-19, pl. 9, figs. 15-22, text-fig. 11; Roemer, 1880, Lethaea palaeoz., 1 Th., p. 294; Etheridge, 1888, Foss. Brit. Isles, p. 2; Ami, 1894, Ottawa Nat., 8, no. 6, p. 2; Head, 1895, Palaeoz. sponges, pp. 5-12; Bassler, 1915, Bull. U.S. Nat. Mus. 92, p. 855; Raymond, 1916, Bull. Mus. Comp. Zool., 56, no. 3, p. 238; Grabau, 1916, Bull. Geol. Soc. Amer., 27, p. 577; Twenhofel, 1928, Geol. Surv. Canada Mem., 154, p. 101; Shimer and Shrock, 1944, Index fossils, p. 57; Laubenfels, 1955, Treatise Inv. Paleontol., p. 110; Walton, 1965, Lower Palaeoz., p. 192.
- Paceolus dactiolooides* Hansman and Scott, 1967, Jour. Paleontol., 41, p. 1,023.
- Pasceolus billingsi* Roemer, 1888, Neu. Jahr. Min. Geol. Pal., Band 1, pp. 74-75; Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, pp. 205, 212, 213, 216, 228.
- Pasceolus dactiolooides* Meek and Worthen, 1868, Geol. Surv. Ill., 3, pp. 345, 346, pl. 5, figs. 2a-c; Calvin, 1893, Amer. Geol., 12, p. 54; Calvin, 1893, Proc. Iowa Acad. Sci., 1, pt. 3, p. 13; Head, 1895, Palaeoz. sponges, p. 6; Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, pp. 212, 213, 216.
- Receptaculites dactiolooides* Roemer, 1876, Lethaea palaeoz., 1 Th., p. 289; Miller, 1877, Amer. Palaeoz. fossils, p. 43; Whitfield, 1882, Ann. N.Y. Acad. Sci., 2, art. 13, p. 199; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 798; Whitfield, 1890, Ann. N.Y. Acad. Sci., 5, p. 520; Whitfield, 1894, Rept. Geol. Surv. Ohio, 7, p. 420; Head, 1895, Palaeoz. sponges, p. 6.
- Sphaerospongia* Collinson, 1959, Guide fossil hunters, pl. 1, 2 figs.

Definition.—Thallus spherical or ovoid, never elongated; main axis much inflated apically; lateral shafts thin; lateral heads dilate twice forming two layers of heads; facets mostly six-sided, very regular; heavy calcification of facets, main axis uncalcified.

Discussion.—This species has been recently redescribed as dasy-clad alga (Nitecki, 1970a). The additional specimens available for

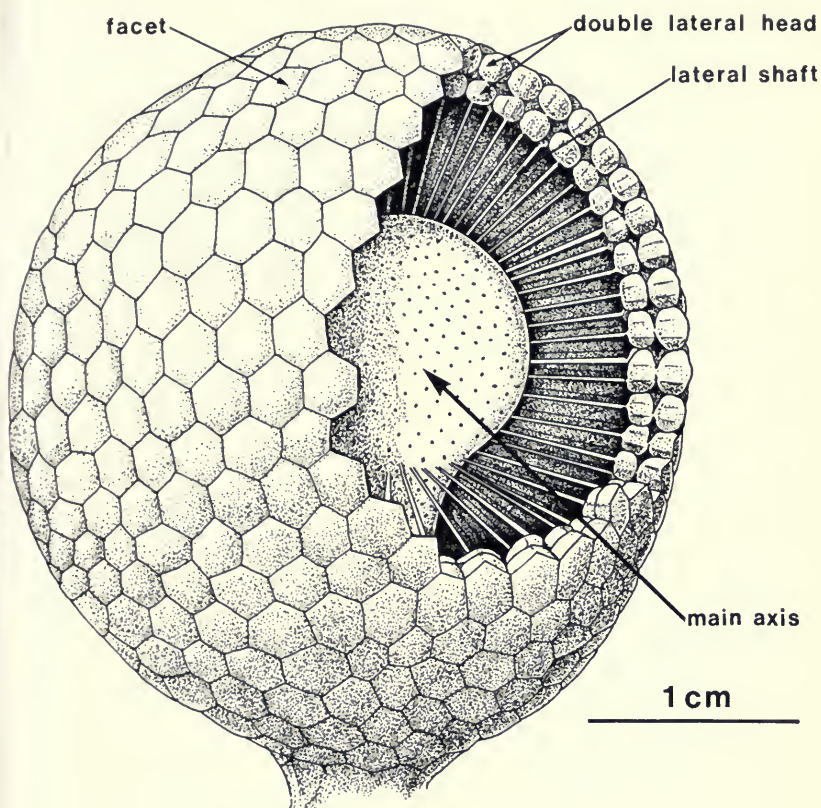


FIG. 12. Reconstruction of *Cyclocrinites dactiolooides*.

study and collected in the field indicate that most *C. dactiolooides* usually inhabited an inter-reef facies. Few specimens only are collected from the reef proper.

Stratigraphic position.—Hopkinton Dolomite, Racine Dolomite, and Joliet Dolomite.

Locality.—Eastern Iowa, Southern Wisconsin, and Northern Illinois.

Holotype.—Unknown.

Referred specimens.—CAS 7988, FMNH P11020, FMNH UC 2: 760, and UIX 31.

Other material.—Very common fossils in many institutions; specimens examined: FMNH, AMNH, PM, UIX, UWM, UIIC, MU, CAS, MCZ, UCMP, OS, USNM.

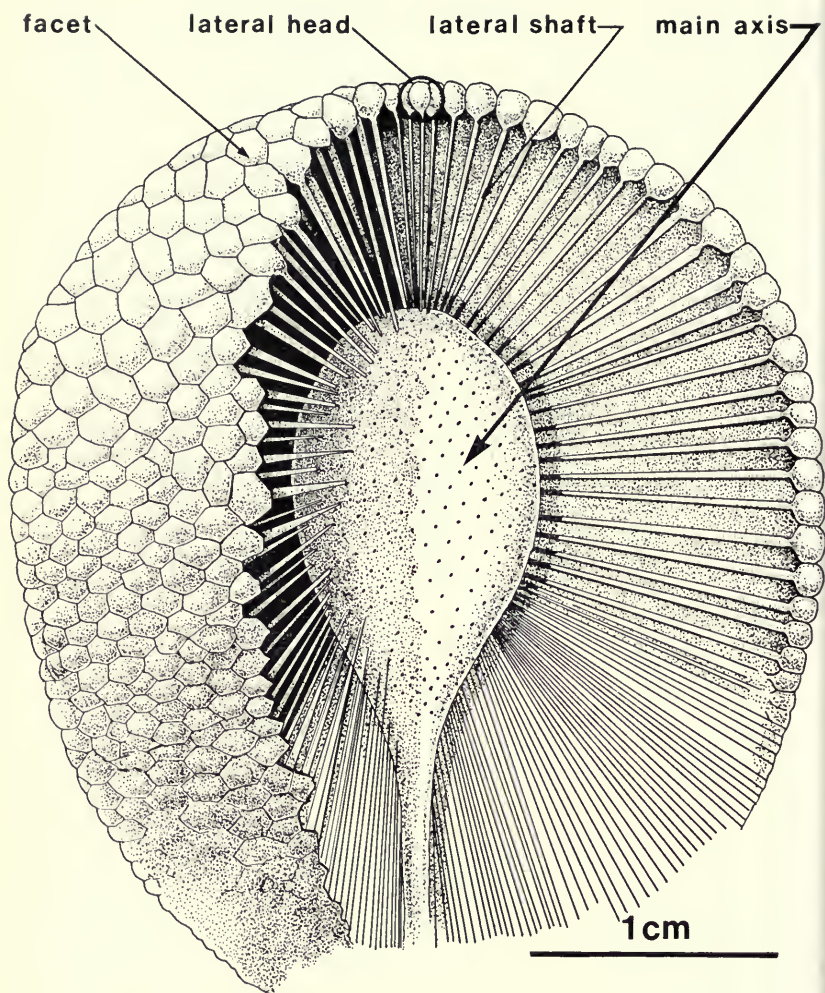


FIG. 13. Reconstruction of *Cyclocrinites gregarius*.

***Cyclocrinites gregarius* (Billings, 1866). Figures 8a, 13, and 14.**

Cyclocrinites gregarius Twenhofel, 1914, Canada Geol. Surv. Mus. Bull., no. 3, p. 13; Twenhofel, 1928, Geol. Surv. Canada Mem., no. 154, pp. 56, 83, 102; Nitecki, 1970, Fieldiana: Geol., **21**, pp. 3, 5, 86–95, 148–149, 166, 167, 169, 170, 173, 175, 178, 180, 181, figs. 3C–D, 21A, 38–40.

Cyclocrinites intermedius Twenhofel, 1914, Canada Geol. Surv. Mus. Bull., no. 3, p. 13; Twenhofel, 1928, Geol. Surv. Canada Mem., no. 154, pp. 55, 58, 83, 101, 102, pl. 1, fig. 10; Dresser and Denis, 1941, Quebec Bur. Mines Geol. Rept. 20, 2, pl. 39, fig. 8; Bolton, 1966, Cat. types, **3**, p. 142.

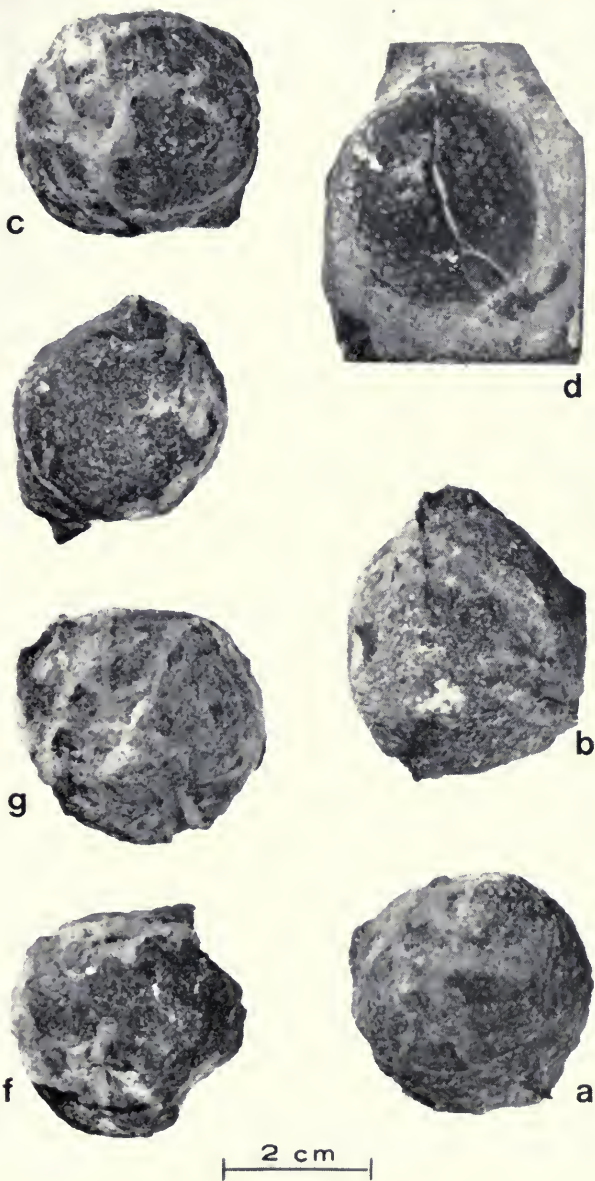


FIG. 14. Seven thalli of *Cyclocrinites gregarius*, originally described by Binns (1866) as *Pasceolus intermedius*. "Syntypes." CGS 2338, 2338 a-d, f and g. Gun River Formation, Anticosti Island, Quebec.

Cyclocrinus gregarius Pia, 1927, Handb. Paläobot., p. 66.

Cyclocrinus intermedius Pia, 1927, Handb. Paläobot., p. 66.

Cyclocrinus (Pasceolus) gregarius Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, p. 215.

Cyclocrinus (Pasceolus) intermedius Stolley, 1896, Archiv. Anthropol. Geol., 1, part 2, p. 215.

Nidulites farus Ami, Ottawa Nat., 8, pp. 83-84, 89.

Nidulites gregarius Bassler, 1915, U. S. Nat. Mus. Bull. 92, p. 855; Roy, 1941, Field Mus., Geol. Ser. Mem., 2, pp. 193, 195.

Nidulites intermedius Bassler, 1915, U. S. Nat. Mus. Bull. 92, p. 855.

Pasceolus gregarius Billings, 1866, Cat. Sil. fossils, p. 72; Bigsby, 1868, Thesaurus Sil., p. 192; Kayser, 1875, Z. Deut. Geol., 27, p. 780; Roemer, 1876, Lethaea Palaeoz., Th.I, p. 296; Miller, 1877, Amer. Palaeoz. fossils, p. 43; Miller, 1889, N. Amer. Geol. Paleontol., p. 162; Head, 1895, Palaeoz. sponges, p. 12; Whiteaves, 1897, Palaeoz. fossils, 3, part 3, pp. 144-145; Dowling, 1901, Geol. Surv. Canada, Ann. Rept., 11, pp. 38, 48, 69, 73, 76, 78, 86; Foerste, 1910, Sci. Lab. Denison Univ. Bull., 16, p. 86; Foerste, 1916, Sci. Lab. Denison Univ. Bull., 18, p. 289; Foerste, 1929, Sci. Lab. Denison Univ. Bull., 24, p. 131; Bolton, 1966, Cat. types, 3, p. 143.

Pasceolus intermedius Billings, 1866, Cat. Sil. fossils, p. 72; Bigsby, 1868, Thesaurus Sil., p. 192; Kayser, 1875, Z. Deut. Geol., 27, p. 780; Roemer, 1876, Lethaea palaeoz., Th.I, p. 296; Miller, 1877, Amer. palaeoz. fossils, p. 43; Miller, 1889, N. Amer. Geol. Palaeontol., p. 162; Head, 1895, Palaeoz. sponges, p. 12; Foerste, 1909, Sci. Lab. Denison Univ. Bull., 14, p. 304; Foerste, 1910, Sci. Lab. Denison Univ. Bull., 16, p. 86; Bolton, 1966, Cat. types 3, p. 143.

Definition.—Like *C. dactiolooides* except thallus smaller and only one set of lateral heads present.

Discussion.—The species has been revised by Nitecki (1970a). It differs from *C. dactiolooides* in the smaller size of the thallus, in the formation of a single lateral head, and in its lower stratigraphic distribution.

Stratigraphic position.—Becsie Formation, Gun River Formation, Kankakee Dolomite. Possibly Ellis Bay Formation.

Locality.—Anticosti Island, Quebec, and Northwestern Illinois.

Holotype.—CGS 2230.

Referred specimens.—CGS 2230a, 2230c, 2230d, 2338, 2338a, 2338b, 2338c, 2338d, 2338f, 2338g, 8131.

Other material.—CGS, FMNH.

Tribe Calathieae Nitecki, 1969

Definition.—Thallus simple or rarely divided, globose, elongate or constricted; main axis frequently preserved; laterals in whorls; pri-

mary branches only; stellate structures generally present; rhizoid attachment when present extensive; precipitation of calcium carbonate on outside of thallus and upon main axis forming two walled structures; Cambrian?, Ordovician and Silurian.

Discussion.—The fossils now assigned to the tribe have been described extensively from the Ordovician and Silurian, predominantly from North America, and possible Cambrian occurrences noted (Finks, 1960). They are also known from the Arctic, Manchuria, and Australia. The tribe differs from all other receptaculitids in the whorled arrangement of laterals and in the presence of distinct rhizoidal holdfasts. The shape of the thallus is often very pointed and conical and may even be constricted. The anatomy of the branches, particularly of the lateral heads is ischaditid. The whorled arrangement of branches is that of recent dasycladales. The tribe is systematically reviewed elsewhere (Nitecki, MS).

Calathium Billings, 1865

Definition.—Thallus undivided, elongate, rarely ovoid, commonly apically pointed; stellate structures when present generally four ribbed; small rhizoidal attachment rarely preserved. Cambro?—Ordovician and Silurian.

Type species.—*Calathium formosum* Billings, 1865.

Discussion.—Genus *Calathium* Billings, 1865, differs from the genus *Calathella* Rauff, 1894, mainly in the absence of extensive rhizoidal "roots."

Calathium egerodae n. sp. Figures 8c, 15–20.

Calathium sp. Fisher, 1925, Bull. Ill. Geol. Surv., 51, p. 42, pl. 5, fig. 1; Bretz, 1939, Bull. Ill. Geol. Surv., 65, p. 80, pl. 6, fig. 1; Toomey and Ingels, 1964, Jour. Paleontol., 38, no. 6, p. 1103; Nitecki, 1969, Fieldiana: Geol., 16, no. 14, text-fig. 2.

Name.—This species is thankfully named for Dr. Lois Eubank Egerod who published an excellent paper on the position and relationship of Dasycladales among Siphonous Chlorophycophyta (Egerod, 1952).

Definition.—Thallus elongate, sometimes twisted, apically pointed; shape of thallus possibly ecologically controlled; upper part of thallus calcified, lower uncalcified; main axis pointed, elongate, calcified apically; laterals thin; lateral heads large; stellate structures four ribbed; calcification of distal part of laterals heavy, forming thick wall.

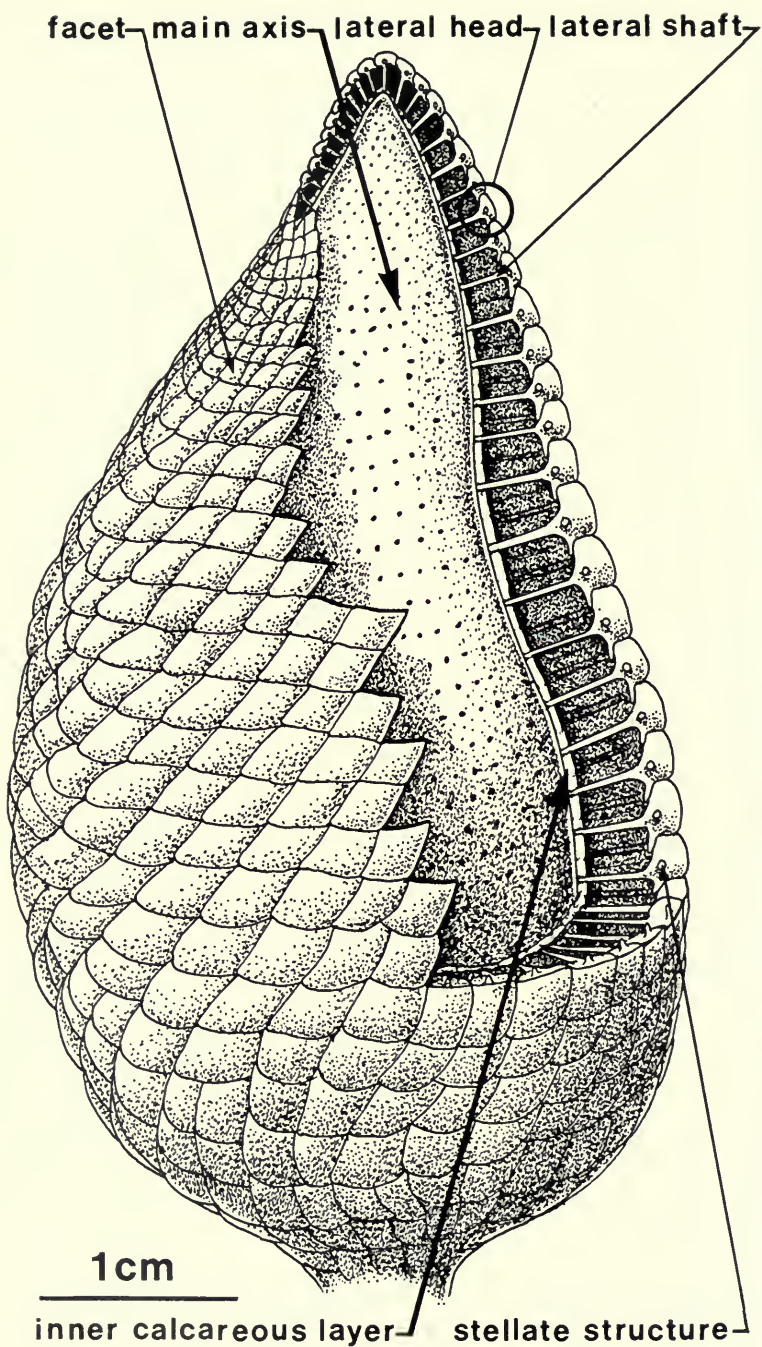


FIG. 15. Reconstruction of *Calathium egerodae*.

Description.—**THALLUS:** The shapes and sizes of thalli vary from almost perfect cones to thin, elongate bodies. The largest specimen is 7.90 cm. tall and the broadest is 5.15 cm. The measurements of the smallest specimens are meaningless because they may represent the broken upper parts of larger individuals. Almost complete thalli have been observed (fig. 16). The complete, undamaged apex is often preserved, however, the lower, older part is always missing. Thalli are seldom flattened out, and thus indicate a relatively rigid skeleton. The algae are often preserved in growth position, and, in addition, many are found lying on their sides. The sometimes slight twisting of the thallus is present, it is, however, less pronounced than the body twist of *Ischadites koenigii* (p. 61).

MAIN AXIS: The main axis is preserved on many specimens (fig. 17). The upper part of the main axis is pointed and is heavily calcified. The uncalcified vesicle expands rapidly in the lower part of the thallus. With the increased thickness of the main axis, the calcification increases, and eventually the main axis is entirely calcified. Thus in lower parts of the thallus the uncalcified main axis is not preserved. The precipitation of calcium carbonate on the upper part of the main axis is so extensive that a solid wall is formed around it (fig. 17b). In the lower part of the body, where calcification is weaker, only a thin film of carbonate is precipitated among the laterals. In the lowermost parts no calcification is evident at all.

LATERALS: Laterals are thin (fig. 18) and terminate with relatively large heads. The heads are packed in a rectangular manner and rhomboidal facets result. Stellate structures are at the base of the lateral head and consist of four ribs (figs. 8c, 20). Horizontal ribs are distal, and vertical ribs are proximal. Often only vertical ribs are preserved, and commonly they are completely obliterated. The insertion of laterals upon the main axis is frequently represented by an opening in the wall of the vesicle. The maximum number of laterals in a whorl is 48, the minimum number of laterals at the apex is four, but eight at that region are frequently observed.

Discussion.—Fisher (1925) illustrated as a sponge a Niagaran *Calathium* sp. from Joliet, Illinois. Bretz (1939) reproduced Fisher's figure. Ingels (1963) illustrated a supposed *Calathium* sp. from flank leposits of the Thornton reef complex. Toomey and Ingels (1964) suggested that the Ingels and Bretz specimens are corals, possibly *Thecia*. Nitecki (1969c) illustrated the thallus, main axis, and laterals of Fisher's specimens. This fossil is now designated the holotype (figs. 17c, 20c) and it forms a part of a larger collection of *C.*

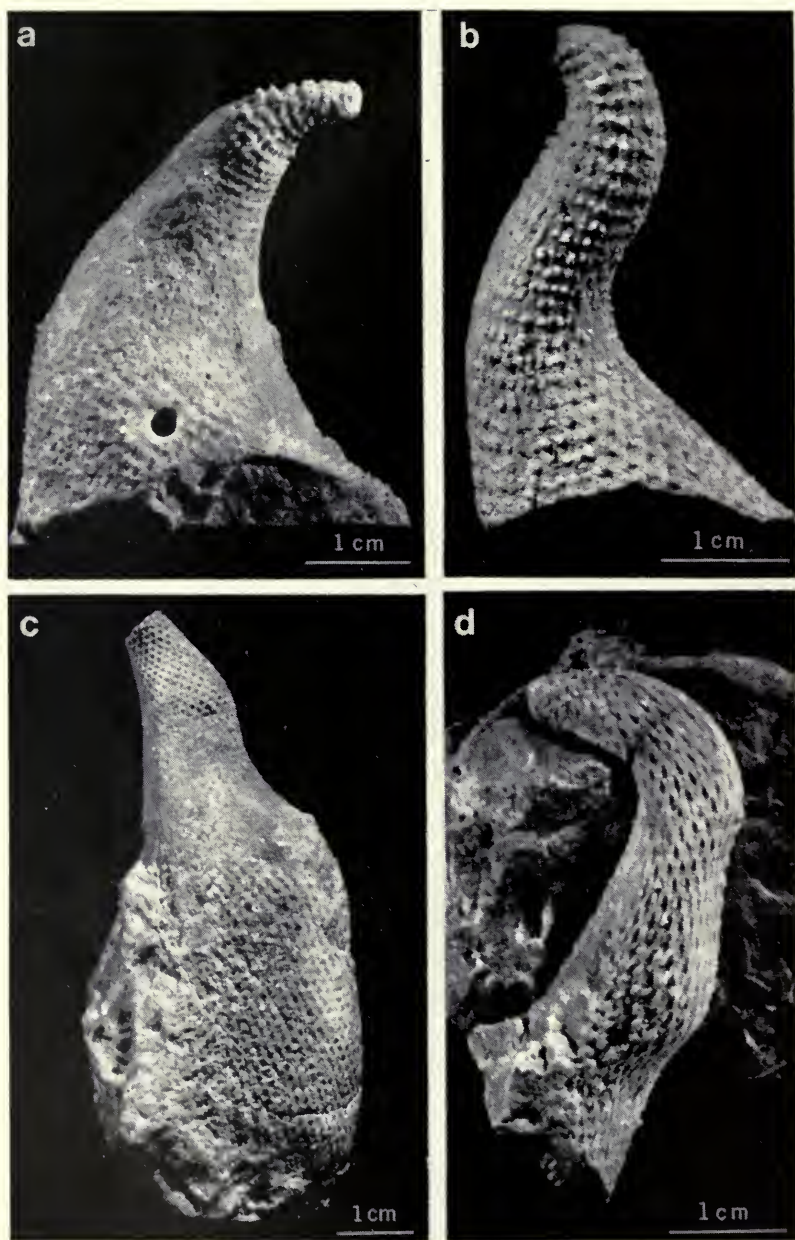


FIG. 16. Four thalli of *Calathium egerodae* from Chicago, Illinois. a, FMNH PP 17542; b, FMNH PP 17569; c, FMNH PP 17540; d, FMNH P 11016. c is almost a complete specimen, a and b show whorled arrangement of laterals.

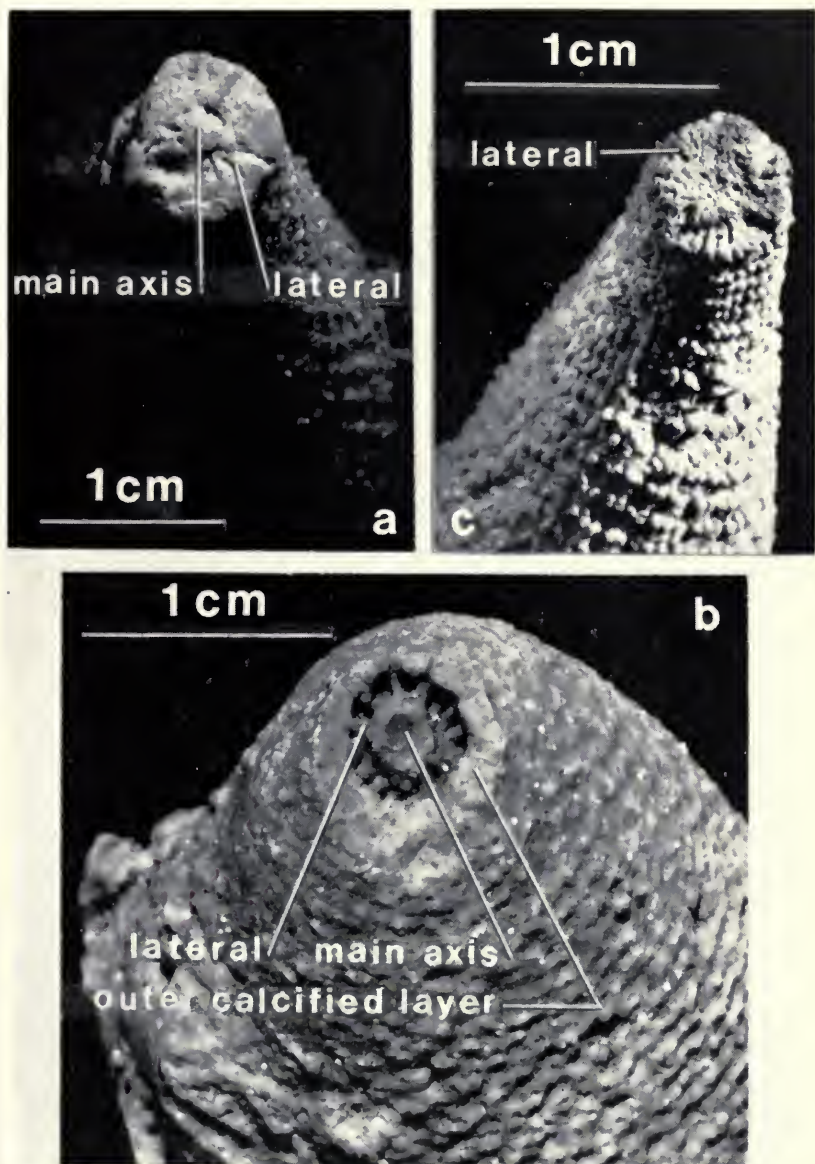


FIG. 17. The upper part of the main axis of *Calathium egerodae*. **a**, heavy calcification throughout, FMNH UC 56265 (after Nitecki, 1969, fig. 2B); **b**, heavily calcified outer zone, FMNH PP 17546; **c**, individual laterals calcified, FMNH UC 4466, holotype.

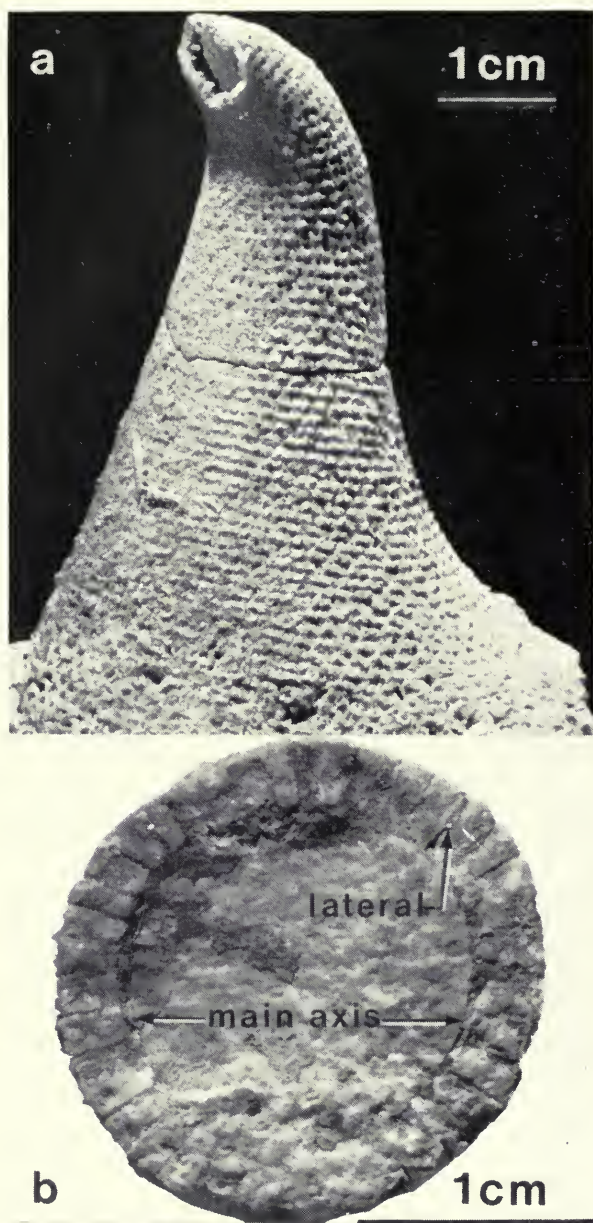


FIG. 18. Thallus and cross-section of *Calathium egerodae*. FMNH P 11015. a, lateral view; b, cross-section.

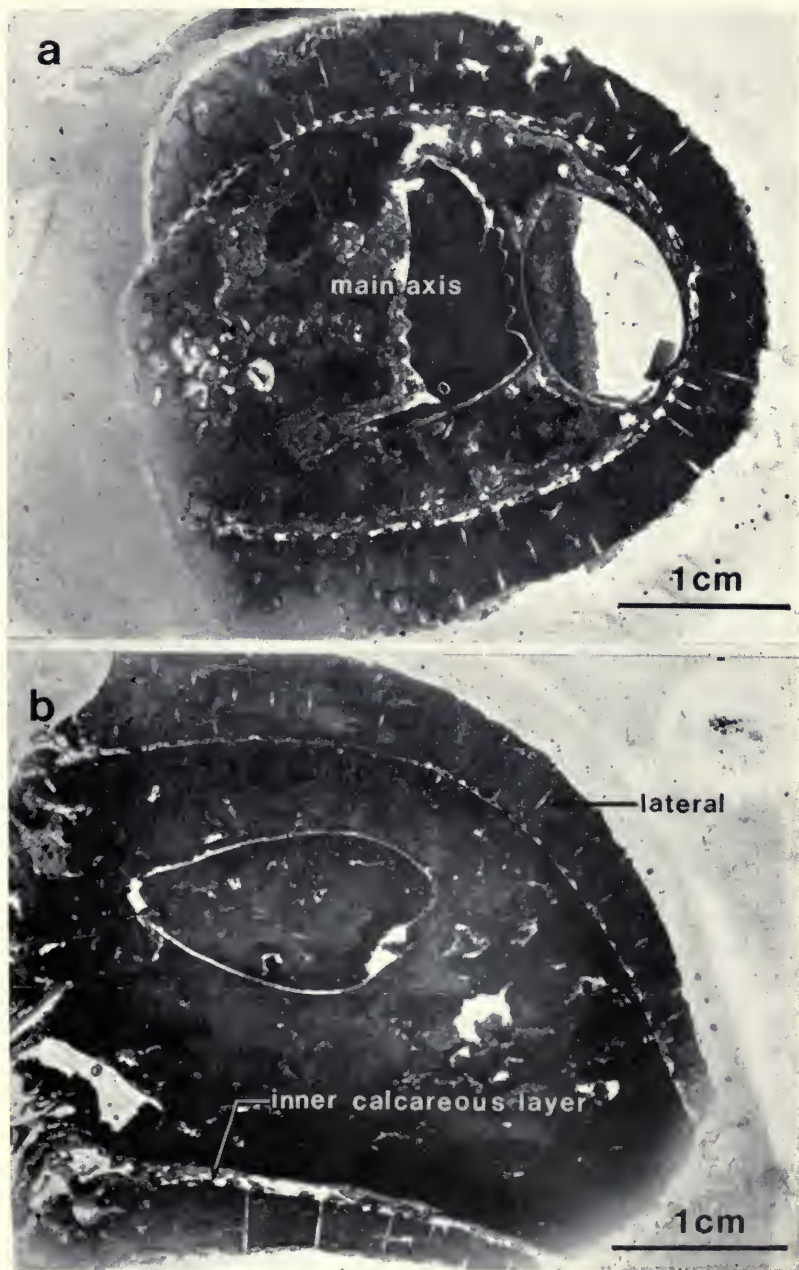


FIG. 19. Sections through thalli of *Calathium egerodae*. a, cross-section, I MNH PP 17578; b, longitudinal section, FMNH PP 17577.

egerodae from the Chicago region. However, Ingels' specimens, now also housed in Field Museum, are not receptaculitids.

The orientation of the thallus, as reconstructed here, is based upon the orientation of many fossils, preserved in growth position in the rock, and upon the anatomy of complete apices. None of the apices studied possess any indication of attachment, many are extremely thin, so thin as to be unable to support the entire plant.

The growth consists of elongation of the thallus with the associated broadening of the older parts. New whorls are added apically, and additional laterals are inserted into older whorls. Young plants possess extremely pointed apices which in older organisms broaden and round off considerably.

The exterior of the thallus is characterized by two different sets of lines formed upon the surface (fig. 20c). The first, created by the edges of rectangular heads, forms sinusoidal lines; the other, created by the ribs of stellate structures, forms a vertical and a horizontal set. This pattern is characteristically receptaculitid (Nitecki, 1969c). The surface is altered by dolomitization and the holes in facets representing cross-sections through laterals are frequently small protuberances (fig. 20a). This is similar to the preservation common among other receptaculitids, particularly *Cyclocrinites dactioides* and *Ischadites*. However, the shape of facets is always rhombohedral and not six-sided, and, because stellate structures are at the base of lateral heads, they are in casts preserved on the bottom of facets. Precipitation of calcium carbonate upon the main axis is heaviest on the top where it forms a solid wall. In the lower parts it fills the spaces between the laterals, and further down in older parts it forms only a thin continuous sheet. The oldest part of the vesicle is not calcified, and hence not preserved in fossils. Sometimes only the fragmentary main axis is preserved.

Preservation and ecology.—All specimens studied are molds and all are dolomitic. Most of the fossils are from the Racine Dolomite from Chicago, Illinois and Racine, Wisconsin and they exhibit many body shapes. The less common Joliet Dolomite specimens from the inter-reef regimen are considerably more erect. It appears that the straight thalli from the deeper quieter waters and the varied thalli from the reef tops are perhaps ecologically controlled.

Calcification.—The calcification of the base of laterals is varied and different structures are thus produced. The common precipitation is in the form of a thin layer that is perforated for the reception

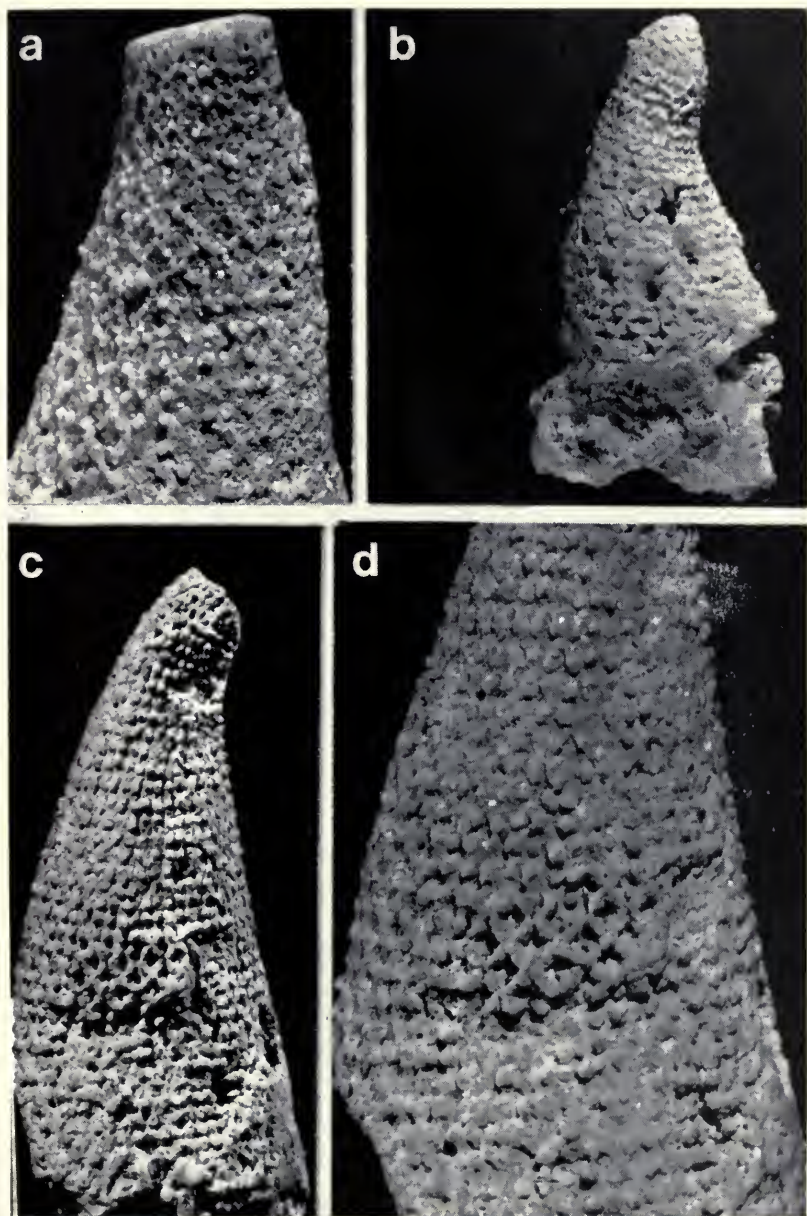


FIG. 20. Surface features of thallus of *Calathium egerodae*. **a**, upper part of thallus FMNH UC 56265 ($\times 2.0$); **b**, "worm" burrows in thallus, USNM 80179 ($\times 1.3$); **c**, holotype, FMNH UC 4666 ($\times 2.0$); **d**, enlargement of **c** ($\times 3.0$).

of laterals. Often the bases of laterals are enlarged and heavily calcified and form distinct protuberances upon the main axis. The precipitation of carbonate can also occur on the main axis and upon the bases of laterals, thus forming two thin zones of precipitate. The most modified manner of precipitation is the more or less continuous but perforated precipitation upon the main axis and an interrupted precipitation on the bases of laterals. A double head effect is thus produced.

Relationship.—This species (as well as all calathiids) differs from the other receptaculitids in the whorled arrangement of laterals. It also differs from all American Silurian receptaculitids in the presence of a distinct heavy calcification of the main axis. However, its sometimes ovoid shape of the thallus, its occasional twist of the axis, and the appearance of the exterior of the thallus are very similar to *Ischadites koenigii*. The double-walled precipitation of carbonate is similar to the calcification of certain *Receptaculites*. However, *Ischadites koenigii* that appear to have had two walls are also found.

Stratigraphic position.—Top of reef in Racine Dolomite, occasionally reef flanks and inter-reef facies in Joliet Dolomite.

Locality.—Bridgeport Quarry, Chicago; Thornton Quarry, suburb of Chicago; Romeoville, Will County, and near Joliet, Illinois, and Racine, Wisconsin.

Holotype.—FMNH UC4666.

Other material.—FMNH, USNM.

Tribe Receptaculiteae Nitecki, 1969

Definition.—Thallus unbranched, globose up to 40 cm.; main axis heavily calcified, non-calcified, weakly calcified or absent in adult form; when present globose; first degree laterals only; laterals in well-packed spiral; branches of uniform length; lateral heads consist of stellate structures and cortical plates; frequently complete incrustation with calcium carbonate; solitary; cosmopolitan; Ordovician to ?Permo-Carboniferous.

Discussion.—In North America two Silurian genera are recognized—*Receptaculites* and *Ischadites*. The third name, *Sphaerospongia* Pengelly, 1861, is generally given in North America to certain Devonian receptaculitids that appear to have hexagonal facets. The internal anatomy of this genus is not well known and the preliminary examination of American Devonian fossils indicates that

these perhaps may be closely related to *Ischadites*. No American Silurian "*Sphaerospongia*" are available for study.

Receptaculites Deshayes, 1828

Definition.—Thallus large; main axis generally globose, frequently pointed, sometimes absent in adult; laterals short and straight; lateral heads modified forming often complicated stellate structures and plates; calcification of laterals heavy; external calcification and that of lateral bases forms double wall. Ordovician through Devonian.

Type species.—*Receptaculites neptuni* (Defrance, 1827).

Discussion.—In North America the genus *Receptaculites* is generally considered to consist of fossils with short, stout branches. The inner ends of branches are modified and "plates" similar to outer "plates" form. The outer and inner plates are almost solidly fused together and two walled structures result. In this respect *Receptaculites* is similar to *Calathium*. However, little is known about the main axis of *Receptaculites*. It is possible that by analogy with the better understood and better preserved *Ischadites* the short branches of *Receptaculites* represent only the distal part of the lateral in a manner of the distal lateral of *Ischadites prismaticus*. At the present time, however, the preserved branch of *Receptaculites* is interpreted as complete and thus comparable to the branch of *Calathium*.

Receptaculites sacculus Hall, 1879. Figures 8d, 21, 22.

Receptaculites Hall, 1883, 12th Ann. Rept. Ind. Dept. Geol., p. 244.

Receptaculites sacculus Hall, 1879, Descript. new foss. Waldron, pp. 1-2; Hall, 1882, 11th Ann. Rept. Geol. Surv. Ind., p. 222, pl. 1, fig. 5; Hall, 1882 [1883], Trans. Albany Inst., 10, pp. 57-58; S. A. Miller, 1883, Amer. Palaeozoic fossils, 2nd ed., p. 261; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 846; Lesley, 1889, Geol. Surv. Penn Rept. P4, 2, p. 855, text-fig.; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 164; Head, 1895, Palaeozoic sponges, p. 4; Winchell and Schuchert, 1895, Geol. Minn., 3, pt. 1, p. 61; Kindle, 1898, 22nd. Rept. Ind. Geol. Surv., p. 418; Clarke and Ruedemann, 1903, Bull. N. Y. State. Mus. 65, Paleontol. 8, p. 12; Bassler, 1915, U. S. Nat. Mus. Bull. 92, p. 1098.

Definition.—Large size receptaculitid; thallus probably oval; laterals about one-fifth diameter of thallus; stellate structure of more than four ribs.

Description and discussion.—This species is based upon only one very poorly preserved specimen, and, therefore, few details of its anatomy can be learned. Its nature as a receptaculitid has been

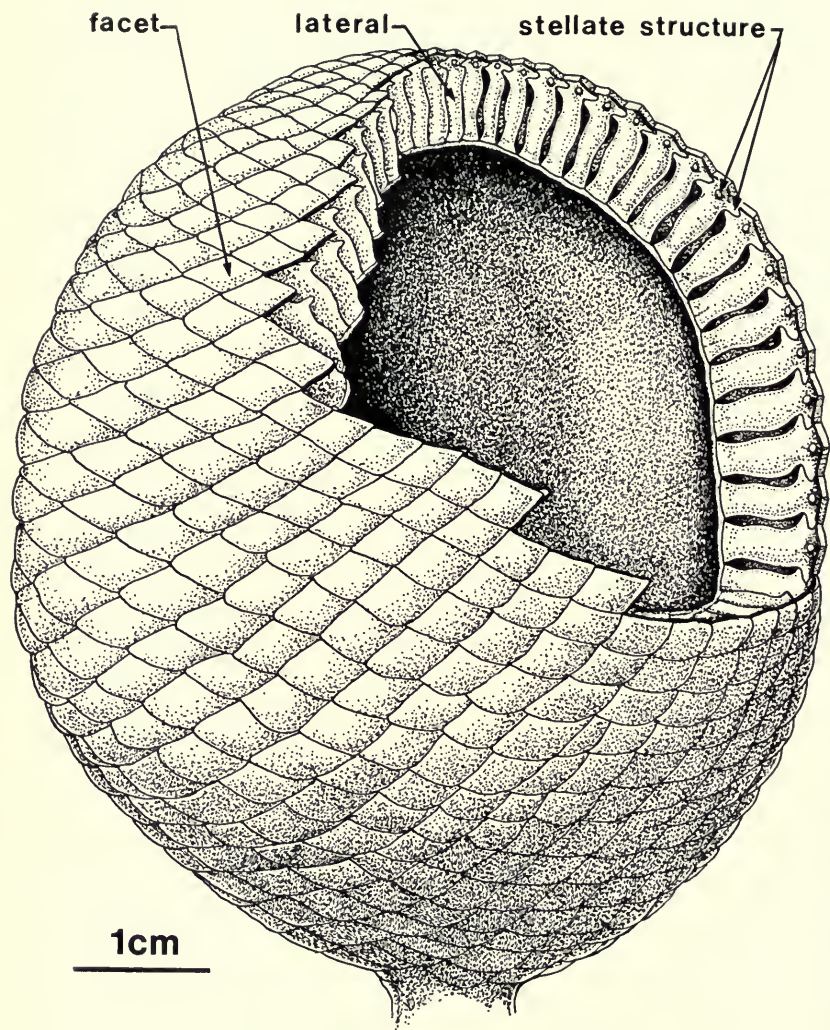


FIG. 21. Reconstruction of *Receptaculites sacculus*.

questioned by Winchell and Schuchert (1895) who probably did not examine the holotype. The type indeed possesses characters that easily allow it to be placed in the genus *Receptaculites*. These are the thick, short branches, and the relative complexities of the ends of the primaries. The details of the branches and of their stellate structures are, however, unknown. The fossil consists of a small por-



FIG. 22. Holotype of *Receptaculites sacculus*. NYSM 1040/1. Waldron Shale, Waldron, Indiana.

tion of the thallus only and differs from most other North American species of *Receptaculites* in its possibly ovoid body shape. Because of poor preservation the specimen cannot be placed in any other species and until more specimens are available for examination the name of this species is retained.

Measurements.—Length 8.28 cm.; width 6.25 cm.; length of laterals 1.38 cm.; estimated number of laterals in spiral over 50.

Stratigraphic position.—Waldron Shale.

Locality.—Coon's Creek in town of Waldron, Indiana.

Holotype.—NYSM 1040/1. Collected by C. D. Walcott and C. V. in Deloo, 1878.

Receptaculites sp.

Few poorly preserved fragmentary fossils are tentatively assigned to *Receptaculites* sp. The assignment is based upon: the suggested large size, shortness, and thickness of branches; the external appearance of the thallus; and the similarity of preservation as flat discs.

The facets in these specimens are large and deep and the stellate structures are slightly above the base of the facet. The largest fragmentary specimen is 8.5 cm. across.

Stratigraphic position.—Racine Dolomite and Cedarville Dolomite.

Locality.—Bridgeport Quarry, Chicago, Illinois and Bradford, Ohio.

Material.—FMNH, MU.

Receptaculites sp.

Receptaculites sp. Teichert, 1937, 5th Thule Exped., pp. 25, 26, 122, 123, pl. 1, figs. 2, 3, [?] 6.

Discussion.—Teichert (1937) described and illustrated two fragments of Silurian *Receptaculites* sp. from King William Land. One fragment (Teichert, pl. 1, figs. 2–3) appears to be Silurian. His second specimen (Teichert, pl. 1, fig. 6) is a mold indistinguishable from the Ordovician *Receptaculites oweni*. Since these fossils are not available for study, the taxonomic decision cannot be made, except that Teichert's assignment to the genus *Receptaculites* is correct.

Stratigraphic position.—Silurian.

Locality.—Hinterland of Douglas Bay, N.W. of Peffer River, southeastern King William Land, Northwest Territories, Canada.

Material.—Not available.

Ischadites Murchison, 1839

Definition.—Main axis globular, sometimes pointed, rarely calcified, sometimes twisted; lateral shaft thin, elongate, progressively calcified; proximal ends of laterals generally non-calcified, or weakly calcified; laterals sometimes claviform, sometimes modified into rays; diversified stellate structures and cortical facets present; stellate structures commonly three or four ribbed, sometimes more; facets four sided, often five or six sided; basal attachment small; Ordovician to Devonian.

Type species.—*Ischadites koenigii* Murchison, 1839.

Discussion.—The Silurian *Ischadites koenigii* from England possesses laterals on the upper part of the main axis only. The laterals expand terminally to form heads; only one set of laterals exists, and all branches are similar and of approximately the same size. *Ischadites elrodi*, a North American Lower Devonian species resembling *I. koenigii*, has laterals distributed throughout the main axis and not only upon its upper bulbous part. In addition, the number of laterals appear smaller than in *I. koenigii*. *Ischadites stellatus* ranges stratigraphically from Silurian to Devonian and possesses two sets of stellate structures. The second upper layer may possibly represent the calcified gametangia. *Ischadites abbottae* of approximately the same stratigraphic and geographic distribution as *I. hemisphericus* possesses two distinct sets of laterals. The upper branches are broad and gently tapering toward the main axis; the lower laterals are thin and rapidly expanding in a typical ischaditid manner. The laterals of *Ischadites hemisphericus* have two different kinds of heads. All laterals are thin and expand rapidly at their termini. The upper branches have large heads with poorly calcified, or non-calcified stellate structures. The lower branches expand into small heads with heavily calcified and interlocking stellate structures. It appears that in *I. hemisphericus* the gametangia may have been carried in the heads of the upper laterals. The lateral shaft of the poorly known *I. burntensis* is similar to the branch of *I. abbottae*. However, the lateral head of *I. burntensis* is double. *I. subturbinatus* and *I. planoconvexus* are the only Silurian North American species with considerable compaction and with flattened bodies. *I. prismaticus* possesses a unique ray, a modification of the lateral.

Ischadites hemisphericus is an important "link" between Cyclo-riniteae and Receptaculiteae and exhibits the algal character of receptaculitids well.

Ischadites koenigii¹ Murchison, 1839. Figures 4, 5, 8e, 9, 23–29.

Acanthoconia barrandei Pribyl, 1944, Vest. Ceske Spolec. Nauk., pp. 1, 6.

Ischadites canadensis Billings, 1863, Geol. Canada, pp. 309, 327, text-fig. 313;

Billings, 1865, Palaeozoic fossils, 1, p. 384; Winchell and Marcy, 1866,

Boston Soc. Nat. Hist. Mem., 1, p. 86; Head, 1895, Palaeozoic sponges, p.

2; Winchell and Schuchert, 1895, Geol. Minn., 3, pt. 1, p. 66; Bassler, 1915,

¹ *I. koenigii* has been spelled in the following ways: *koenigi*, *konigii*, *konigi*, *königi*, *königii*, and *koeniger*. These various forms have been used with lower case or capital K. In this synonymy list the different spellings are not recognized.

Bull. U. S. Nat. Mus. 92, p. 668; Howell, 1943, Bull. Wagner Free Inst. Sci., 18, no. 4, pp. 36, 37; Bolton, 1966, Cat. type fossils, 3, p. 142; Nitecki, 1969, Geol. Soc. Amer., p. 33.

Ischadites infundibulum Howell, 1943, Wagner Free Inst. Sci. Bull., 18, no. 4, pp. 35-37, 41, pl. figs. 1, 2.

Ischadites koenigii Murchison, 1839, Sil. System, pp. 697-698, 712, pl. 26, fig. 11; Owen, 1844, Rept. Geol. Expl., p. 70; Murchison, 1854, Siluria, p. 217, pl. 12, fig. 6; Billings, 1857, Canada Geol. Surv. Rept. Progress, 1853-56, p. 342; Murchison, 1859, Siluria, 3rd ed., pp. 246, 535, pl. 12, fig. 4; Hall, 1863, 16th Ann. Rept. N.Y. Cab. Nat. Hist., p. 68; Billings, 1863, Geol. Canada, p. 327; Billings, 1866, Cat. Sil. Fossils Anticosti, p. 69; Winchell and Marcy, 1866, Boston Soc. Nat. Hist. Mem., 1, p. 86; Bigsby, 1868, Thesaurus Sil., pp. 3, 194; Murchison, 1872, Siluria, 5th ed., p. 509; Salter, 1873, Cat. Camb. Sil. fossils, p. 100, 2 text-figs.; Gümbel, 1876, Abh. K. bayer. Akad. Wiss., Bd. 12, Abth. 1, pp. 40, 43, pl. A, figs. 28-30; Nicholson and Etheridge, 1878, Sil. fossils Girvan, pp. 20, 21; Quenstedt, 1878, Petref. Deutschl., 5, p. 592; Zittel, 1880, Handb. Palaeontol., p. 728; Roemer, 1880, Lethaea Palaeoz., I Th., pp. 291, 292; Jones, 1882, Cat. Foraminif., pp. 2, 3; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, pp. 796, 797, 801, 802, 805, 810, 811, 820, 836-837, 839, 844, pl. 36, figs. 1, 1a-1o; Hinde, 1887, Monogr. Brit. Fossil sponges, part 1, pp. 8, 22, 25, 34, pl. 2, figs. 1, 1a, 1b; Hinde, 1888, Monogr. Brit. fossil sponges, part 2, pp. 120-122, 130, 186; Etheridge, 1888, Foss. Brit. Isles, pp. 2, 390; Winchell and Schuchert, 1895, Geol. Minn., 3, part 1, p. 65; Head, 1895, Palaeoz. sponges, pp. 2, 4; Miller and Gurley, 1896, Ill. State Mus. Bull. 11, p. 49; Howell, 1943, Wagner Free Inst. Sci. Bull., 18, no. 4, pp. 37, 38, 39; Pribyl, 1944, Vest. Ceske Spolec. Nauk., pp. 1, 5, 6, 7, 9; Lamont, 1947, Geol. Mag., 84, no. 4, p. 194; Laubenfels, 1955, Treat. Inv. Paleontol., part E, p. 110, fig. 89.3; Lehman, 1964, Rept. Geschiebe., pp. 84-87, text-figs. 1-3; Anonymous, 1966, Brit. Paleoz. fossils, pp. 35, 37, 38, 39, 41, pl. 15, fig. 7; Hucce and Voigt, 1967, Einführ. Geschiebe., p. 58, pl. 10, fig. 8; Nitecki, 1969, Geol. Soc. Amer. Ann. Mtg., p. 33; Nitecki, 1969, Fieldiana: Geol., 16, no. 13, pp. 341-358, figs. 1-15; Nitecki, 1969, Fieldiana: Geol., 16, no. 14, pp. 373, 374, 375, figs. 9A-F.

Ischadites cf. koenigii Pribyl, 1944, Vest. Ceske Spolec. Nauk., p. 2, pl. figs. 3-4.

Not Ischadites cf. koenigii Twenhofel, 1928, Geol. Surv. Canada Mem. 154, p. 103.

Ischadites tessellatus Winchell and Marcy, 1866, Boston Soc. Nat. Hist. Mem., 1, pp. 81, 85-86, pl. 2, fig. 3; Hall, 1867, 20th Ann. Rept. N.Y. State Cab. Nat. Hist., pp. 390, 395; Bigsby, 1868, Thesaurus Sil., pp. 3, 194; Hall, 1870, 20th Ann. Rept. Regt. Univ. State N. Y., rev. ed., p. 435; Hall, 1871, Geol. Surv. State Wisc. 1859-1863, p. 91; Murchison, 1872, Siluria, p. 509; S. A. Miller, 1877, Amer. Palaeoz. fossils, p. 43; Roemer, 1880, Lethaea palaeoz., I Thiel, p. 292; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 839; Walcott, 1884, U. S. Geol. Surv. Monogr., 8, p. 67; Etheridge, 1888, Fossils Brit. Isles, p. 390; Hinde, 1888, Monogr. Brit. Fossil sponges, part 2, p. 119; Head, 1895, Palaeoz. sponges, pp. 2, 4; Winchell and Schuchert, 1895, Geol. Minn., 3, pt. 1, p. 66; Nitecki, 1965, Fieldiana: Geol., 13, pp. 501-502; Nitecki, 1969, Geol. Soc. Amer. Ann. Mtg., p. 33.

Receptaculites canadensis Billings, 1865, Palaeozoic fossils, 1, pp. 384-385, 387, text-fig. 362; Billings, 1865, Canad. Nat. Geol., ser. 2, 2, pp. 191, 193, 197, text-fig. 10; Bigsby, 1868, Thesaurus Sil., p. 4; S. A. Miller, 1877, Amer. Palaeoz. fossils, p. 43; Nicholson and Etheridge, 1878, Sil. fossils Girvan, p. 20; Roemer, 1880, Lethaea palaeoz., I Theil, p. 289; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, pp. 800, 844; Head, 1895, Palaeozoic sponges, p. 4; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 163; Williams, 1919, Canada Geol. Surv. Mem. 111, p. 35, pl. 5, fig. 1; Caley, 1940, Geol. Surv. Canada, Mem. 224, p. 35.

Receptaculites formosus Meek and Worthen, 1870, Proc. Acad. Nat. Sci. Phila., 22, pp. 22-23; Worthen and Meek, 1875, Geol. Surv. Ill., 6, p. 500, pl. 24, fig. 1; S. A. Miller, 1877, Amer. Palaeoz. fossils, p. 44; Roemer, 1880, Lethaea Palaeoz., I Theil, p. 289; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 839; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 163; Head, 1895, Palaeoz. Sponges, p. 4; Hansman and Scott, 1967, Jour. Palaeontol., 41, no. 4, p. 1026; Nitecki, 1969, Geol. Soc. Amer. Mtg., p. 33.

Receptaculites infundibulum Hall, 1861, Rept. Supt. Geol. Surv. Wisc., p. 16; Hall, 1863, 16th Ann. Rept. N. Y. State Cab. Nat. Hist., p. 68; Bigsby, 1868, Thesaurus Sil., p. 4; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 164; Head, 1895, Palaeoz. Sponges, p. 4; Whitfield, 1895, Amer. Mus. Nat. Hist., 1, pt. 2, p. 46, pl. 5, figs. 1, 2; Winchell and Schuchert, 1895, Geol. Minn., 3, part 1, p. 66; Whitfield and Hovey, 1899, Amer. Mus. Nat. Hist., 11, pp. 78-79; Teller, 1911, Wisc. Nat. Hist. Soc. Bull., 9, no. 4, p. 187; Squires and Hawkins, 1958, Amer. Mus. Nov., 1913, p. 13; Nitecki, 1969, Geol. Soc. Amer. Ann. Mtg., p. 33.

Receptaculites infundibulus Hall, 1862, Rept. Geol. Surv. Wisc., 1, p. 429; Hall, 1867, 20th Ann. Rept. N. Y. State Cab. Nat. Hist., pp. 390, 395; Hall, 1870, 20th Ann. Rept. Regt. Univ. State N. Y., rev. ed., p. 435; Hall, 1871, Geol. Surv. State Wisc. 1859-1863, p. 91; S. A. Miller, 1877, Amer. Palaeoz. fossils, p. 44; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 839; Walcott, 1884, U. S. Geol. Surv. Monogr., 8, p. 67.

Receptaculites pedunculatus Twenhofel, 1938, Trans. Wisc. Acad. Sci., 31, pp. 545-546, 2 text-figs.; Nitecki, 1969, Geol. Soc. Amer. Mtg., p. 33.

Receptaculites tessellatus S. A. Miller, 1883, Amer. Palaeoz. fossils, p. 261; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 164; Bassler, 1915, U. S. Nat. Mus. Bull. 92, p. 1,098; Twenhofel, 1938, Wisc. Acad. Sci. Trans., 31, p. 546; Ball and Greacen, 1946, Chgo. Acad. Sci., sp. publ. 7, p. 14; Greacen and Ball, 1946, Milwaukee-Downer College Bull., p. 11.

Definition.—Shape of thallus varies from oval to irregular; main axis often twisted, often irregular; laterals thin, weakly calcified; stellate structures calcified, commonly four-ribbed, uniformly distributed throughout thallus; facets commonly four often six-sided; calcification heavy around lateral heads, frequent around distal part of laterals, rare on main axis; pedicle attachment small.

Description.—THALLUS: The shapes of thalli vary and may be ovoid (fig. 23), discoid to conical calathiid-like (fig. 25b). However,

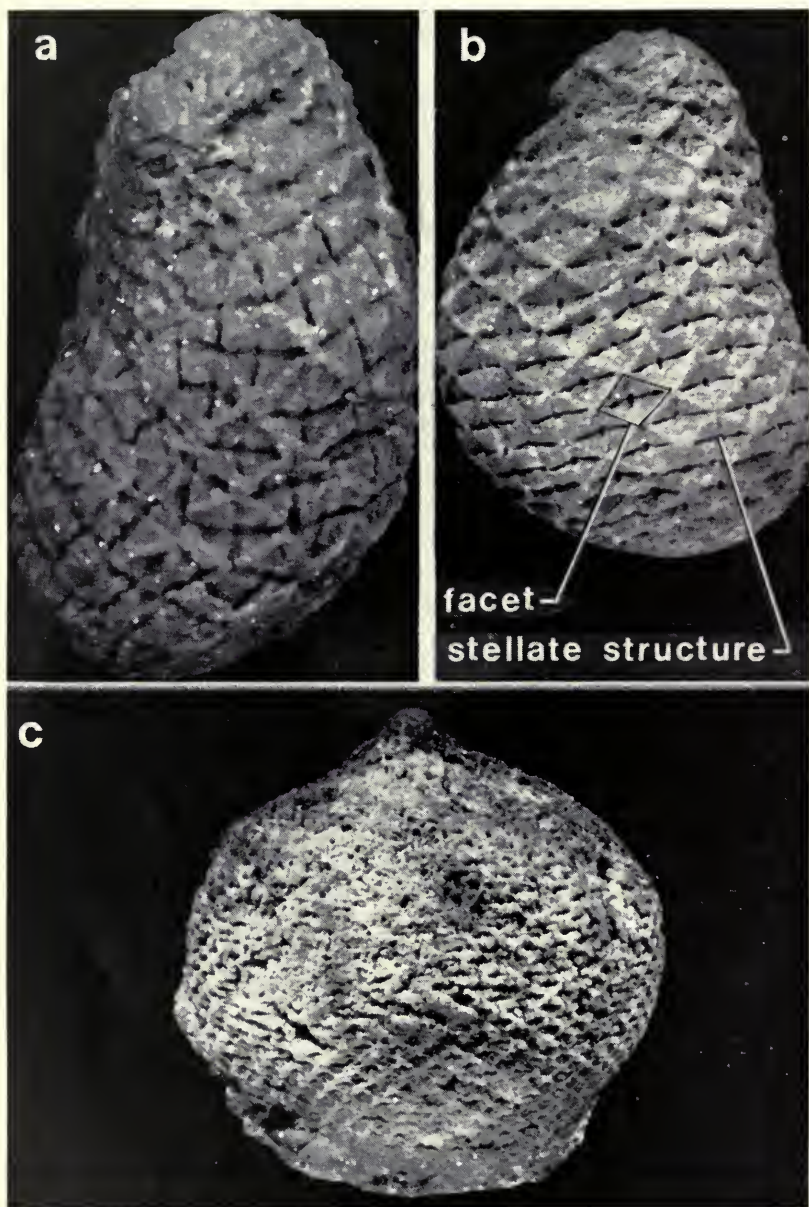


FIG. 23. Regular-shaped thalli of *Ischadites koenigii* from Chicago, Illinois. a, FMNH PP 17636 ($\times 3.0$); b, a complete specimen, FMNH PP 17637 ($\times 3.2$); c, a pointed thallus, FMNH UC 44313 ($\times 1.6$).

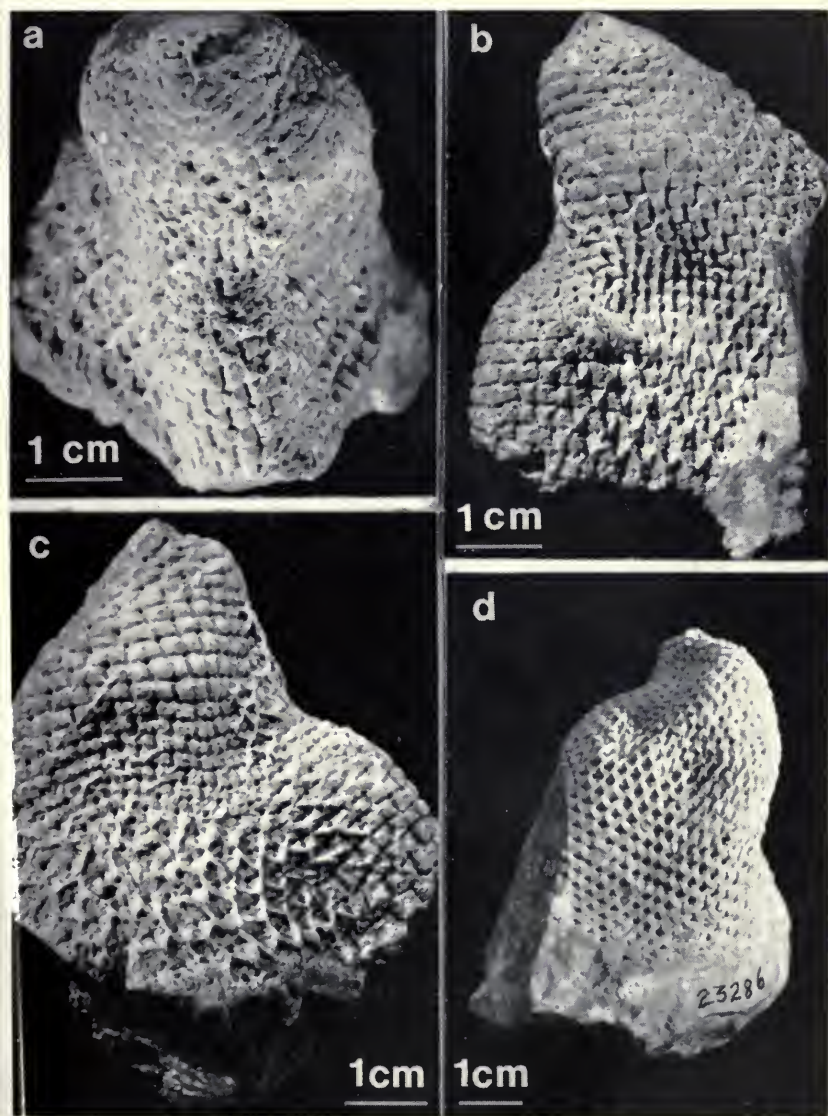


FIG. 24. Irregular-shaped thalli of *Ischadites koenigii*. a, b, c, FMNH PP 1 '635; d, type of *Receptaculites pedunculatus*, PM 23286. a, apical view; b, c, and d lateral views.

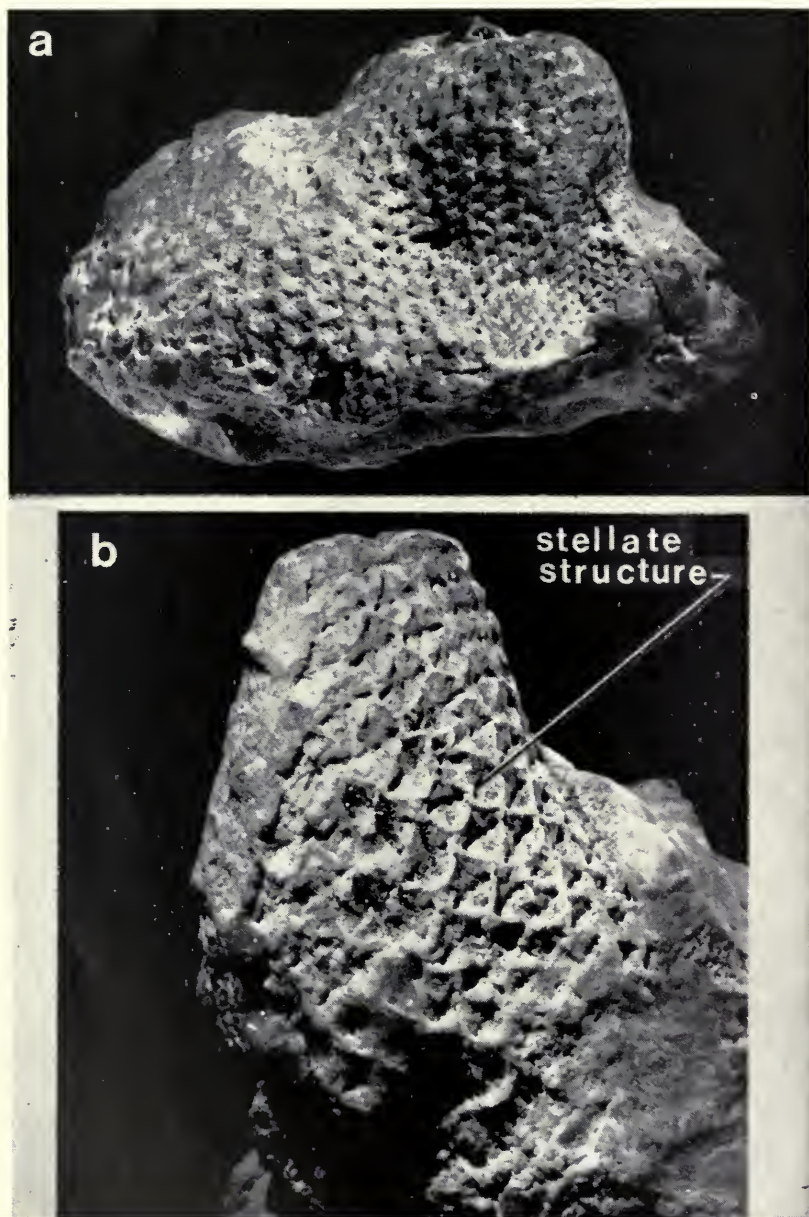


FIG. 25. Irregular and elongate shapes of thalli of *Ischadites koenigii* from Chicago, Illinois ($\times 1.8$). a, FMNH PP 17668; b, FMNH PP 17647.

most irregular shapes of thalli are very common (figs. 4, 24). The variation is so great that the species can be considered "plastic" with respect to its body shape. Certain distorted specimens almost suggest a branched main axis; however, even the most unusual fossils possess a regular and even arrangement of lateral branches (fig. 24). There is very little distortion that could be attributed to agencies of sedimentation, burial or diagenesis. Many specimens are preserved in growth position, and, therefore, the shapes are probably in large extent ecologically controlled. The most unusual character of this species is the twisting of the body (fig. 5).

MAIN AXIS: The shape of the main axis is as varied as the shape of the thallus. It is probably the shape of the main axis that controls the shape of the thallus. Thus in many specimens the main axis is spiraled in a screw-like manner. It appears that in some specimens more than one turn of a spiral is present. Mostly, however, one incomplete spiral of the axis occurs. An unusual horizontal flattening of the top of the main axis has been observed.

LATERALS: Laterals are carried on the upper, mostly bulbous part of the main axis, are thin (fig. 28), and expand distally into a well-formed head (fig. 8e). At the top of the body there are not less than four and not more than eight laterals in one single first spiral. All laterals overlap. In young specimens when the growing area is still very small proximally the lateral shafts are almost in contact. Later as the main axis thickens they move further apart.

LATERAL HEADS: Lateral heads consist of stellate structures and a plate jointly forming an enlarged terminus of the lateral.

STELLATE STRUCTURES: Generally stellate structures are distributed uniformly throughout the body, and are not restricted to any particular area. They consist commonly of four ribs (fig. 29), but often only three (fig. 26b) or even only two-ribbed stellate structures are found. The ribs are almost always in one plane, and when less than four are present the vertical elements are missing (fig. 23b). The ribs are often fused together with the plate above, and thus form one unit. When somewhat worn, the ribs appear thinner and eventually one element can be found missing. It appears that the vertical, upward-pointing rib may be placed somewhat above the other ribs. In some specimens, particularly the European representatives of the species, the horizontal elements of the ribs are often in older parts of the thallus separated from the vertical ones.

FACETS: The facets on most specimens are four-sided, however, there are many specimens that have six or five-sided facets on the same thallus (fig. 9). Fossils have been also observed that consist exclusively of six-sided facets, these however are incomplete. Thus the four-sided facets are not a rule, as is often the case with many other species. However, what controls the number of walls within a facet is uncertain. It is certainly not the number of ribs of stellate structures, because in most six or four-sided there are either four or three ribs. It, therefore, is probably the nature of packing that produces the rhombic pattern. In some specimens facets are distinctly and exclusively four sided (fig. 5b), in others six-sided facets occur, and in still others a variety of facets are noted upon one thallus. Six-sided facets tend to be on the top and the rhomboidal are below in the older parts of the thallus, however variations of this pattern are common.

In most specimens the facets are arranged with great regularity in spite of the diversities of body shapes.

ATTACHMENT: Few specimens are found with a small scar for the pedicle. This is an unmistakable attachment scar, and the pedicle therefore is assumed to have been very small. Upper parts of the body are almost always preserved, while the lower are frequently missing. The "up" orientation of the plant is clear.

CALCIFICATION: The heaviest calcification is found upon the lateral heads, the weakest on the lowermost parts of the thallus. The main axis is very weakly calcified, and therefore rarely its outline is preserved. Often a layer of carbonate is found precipitated among the distal parts of laterals in a manner similar to the precipitation of carbonate in the recent *Cymopolia* and among calathiids. Thus occasionally a false two-walled appearance is produced. In calathiids the second wall is often produced by heavy precipitation of calcium carbonate upon the main axis—a phenomenon seldom observed in *I. koenigii*. The heaviest calcification is always found upon the upper part of the thallus.

GROWTH: The smallest specimens are ball-like with a lower end somewhat elongate. The plates in young individuals are almost fused with stellate structures which later, in ontogeny, separate farther. The lateral heads are cyclocrinitid-like among younger organisms with little calcification of stellate structures, and with heads round and facets generally six-sided particularly in the upper part of the thallus. As the growth proceeds, the six-sided facets give

way to four-sided, and in the oldest specimens the facets may be even somewhat distorted (fig. 27a); the edges of facets lose their clear cut outlines and appear wrinkled. The main axis in young is often elongate and pointed; with time it fills in and in most older specimens the main axis becomes bulbous. The termini of laterals tend to deepen with age. The smallest specimen observed is 1.34 cm. across. It seems possible that organisms of smaller size were not calcified, and hence are not preserved. The largest fossil is at least 7.1 cm. across.

The growth is definitely in spiral, and a number of these spirals can easily be traced across many fossils. The new laterals are not added as Rauff's (1892) figure 7 suggests, but are in spiral. This growth may be more common than has been previously suspected, and Rauff's interpretation has been based upon incomplete specimens.

Discussion of synonyms.—The following Silurian species are synonyms of *I. koenigii*: *Receptaculites infundibulum* Hall, 1861 (fig. 26b); *Ischadites canadensis* Billings, 1863 (fig. 27b); *Ischadites tessellatus* Winchell and Marcy, 1866 (figs. 27a, d); *Receptaculites formosus* Meek and Worthen, 1870 (fig. 27c); and *Receptaculites pedunculatus* Twenhofel, 1938 (fig. 24d).

The examination of types of *Receptaculites infundibulum* Hall 1861, (fig. 26b) and of the original descriptions of various authors indicates that *infundibulum* is undistinguishable from *I. koenigii* as here defined. The holotype of *Ischadites canadensis* (fig. 27b) is a fragment consisting of calcified facets and stellate structures. It is undistinguishable from the Chicago specimens of *I. koenigii* except for color. The casts of types of *Ischadites tessellatus* (figs. 27a, d) consist of the upper part of a somewhat conical form, and a portion of an outer surface of a common form of *I. koenigii* from the Chicago region. The holotype of *Receptaculites formosus* (fig. 27c) is an almost complete specimen with stellate structures well-delineated and consisting of four ribs. The fossil is pyriform and twisted. It differs from other *I. koenigii* only in the darker color of the rock. The holotype of *Receptaculites pedunculatus* is a specimen of an irregular shape. The sizes and shapes of facets also vary. The stellate structures consist of three or four ribs. The specimen fits well into a series of shapes found in the Midwestern states and does not differ specifically from other fossils of *I. koenigii*.

Many non-American species of *Receptaculites* and *Ischadites* may be synonyms of *I. koenigii* (Hinde, 1884). However, the types of

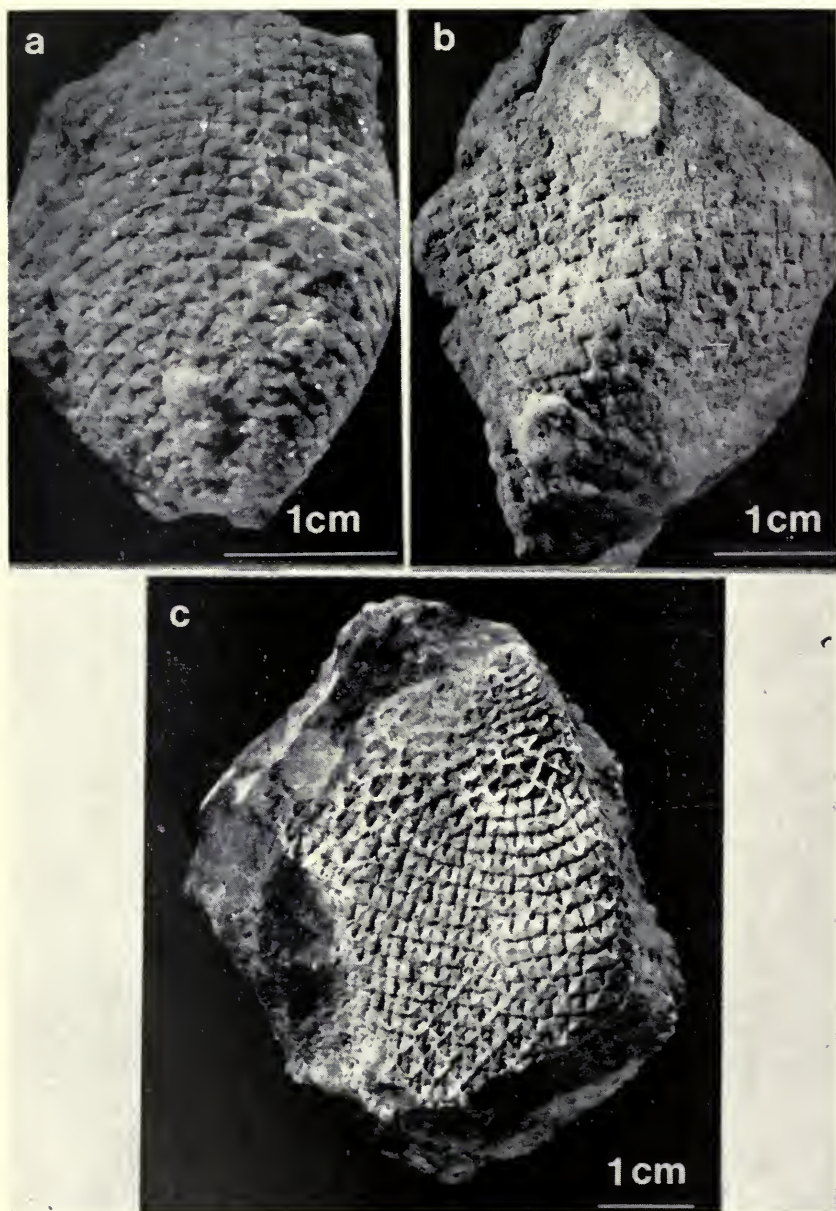
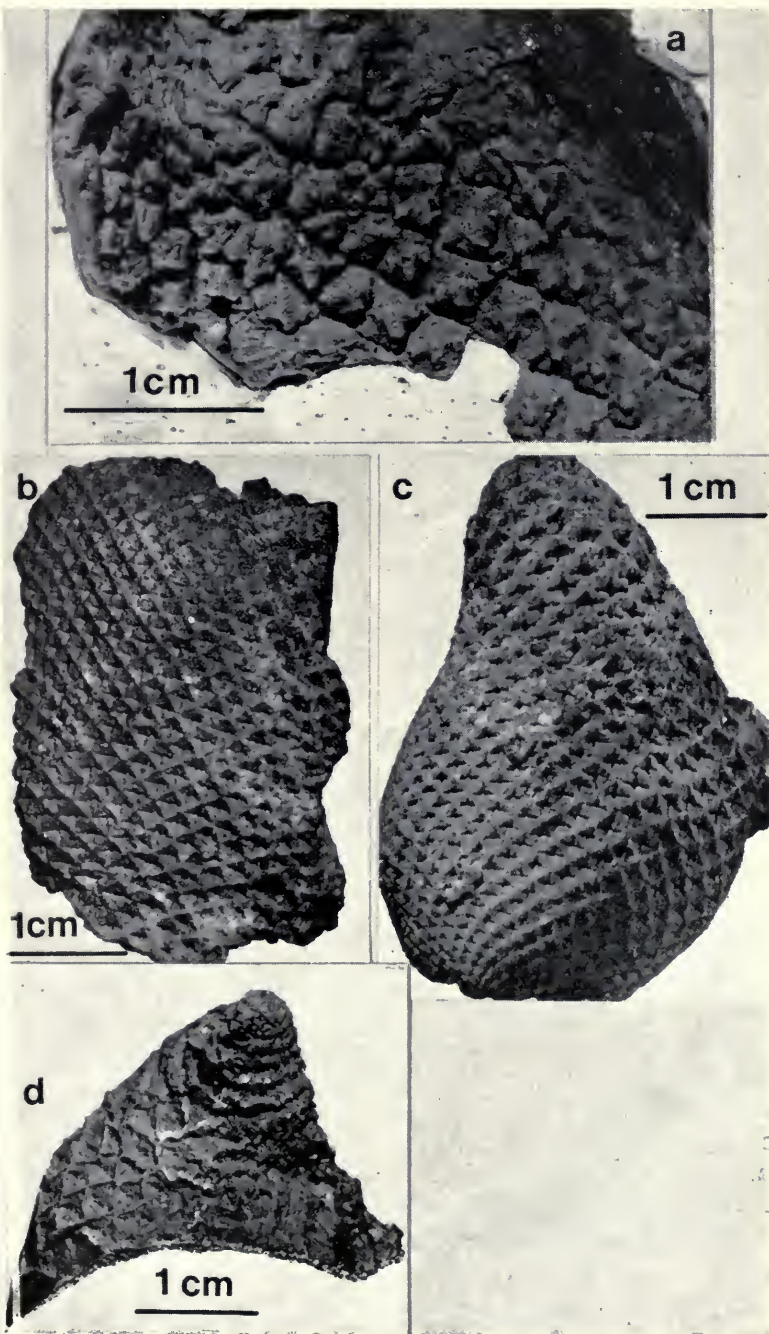


FIG. 26. Surface features of *Ischadites koenigii*. **a**, stellate structures and facets, ETT 321; **b**, stellate structures only (type of *Receptaculites infundibulum* Hall) AMNH 1973; **c**, sinusoidal arrangement of facets superimposed upon the regular arrangement of laterals, FMNH PP 17670. *a* and *c* after Nitecki, 1969, figs. 9C, D.



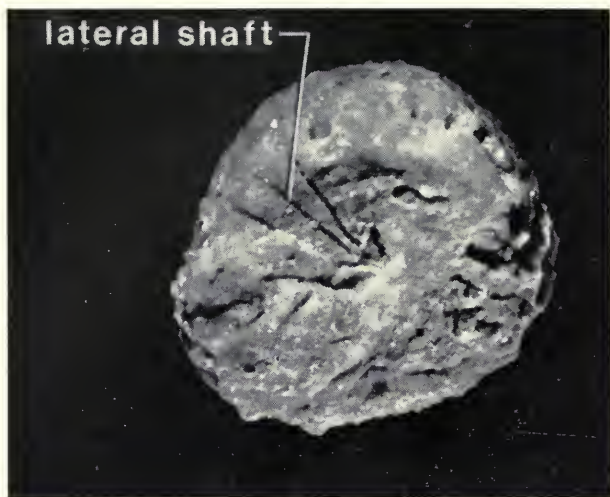


FIG. 28. Shaft of lateral of *Ischadites koenigii* from Chicago. FMNH PP 17640 ($\times 3.5$).

these species are not available for study and therefore no decision on their taxonomy can be made.

Discussion.—*Ischadites koenigii* is the “type species” and therefore an important taxon with many characters upon which the concept of the genus is based. The American representatives of the species are a morphologically “plastic” group. The characters that vary within this species are the shape of the thallus and main axis, the degree of calcification, and the number of ribs of stellate structures. The only relatively constant character is the fairly uniform distribution of lateral heads forming a very regular pattern upon the exterior of the thallus. Nitecki (1969b) recognized and illustrated the spiral growth pattern in the European *I. koenigii*, but misinterpreted the arrangement of laterals upon the main axis. The laterals, although so appearing, are not arranged in whorls but in a tightly packed spiral.

The Silurian representatives of the genus, as well as the Ordovician ischaditids, have generally an erect main axis. The *I. koenigii* and *Calathium egerodae* from the Silurian of North America are the only species so far observed that possess the twisted main axis. It seems,

FIG. 27. Junior synonyms of *Ischadites koenigii*. a and d, casts of holotype of *I. tessellatus* Winchell and Marcy, FMNH UC 763; b, holotype of *I. canadensis* Billings, CGS 2590; c, holotype of *Receptaculites formosus* Meek and Worthen, UIC 11776.

therefore, best not to include in this species *Receptaculites dixonensis* Miller and Gurley which has an erect main axis.

Stratigraphic position.—Racine Dolomite, Cabot Head Shale. Cedarville Dolomite, Osgood Formation.

Locality.—Reef Rock Quarry, near town of Cedarburg, Wisconsin; Bridgeport Quarry, Chicago, Illinois; Cicero, Illinois; Racine, Wisconsin; Limehouse, two miles west of Georgetown, Ontario, Canada; Yellow Springs, Ohio; Big Creek, Jefferson County, Indiana.

Holotype.—BMNH.

Referred specimens.—"Types" of *Receptaculites infundibulum* (six fragments, "syntypes," fig. 26b) AMNH 1973; specimens used by Hall, 1861; by Whitfield, 1895, pl. 5, fig. 2 (specimen figured on his figure 1 is missing); by Howell, 1943 (figure 2 is missing); and by Squires and Hawkins, 1958.

Type of *Ischadites canadensis* CGS2590 (fig. 27b); illustrated by Billings, 1863, fig. 313; Billings, 1865a, fig. 362; Billings, 1865b, fig. 10; Williams, 1919, pl. 5, fig. 1; listed by Bolton, 1966, p. 142.

Casts of types of *Ischadites tessellatus* FMNH UC763 (figs. 27a, 1); described and illustrated by Winchell and Marcy, 1866, pp. 81, 85-86, pl. 2, fig. 3.

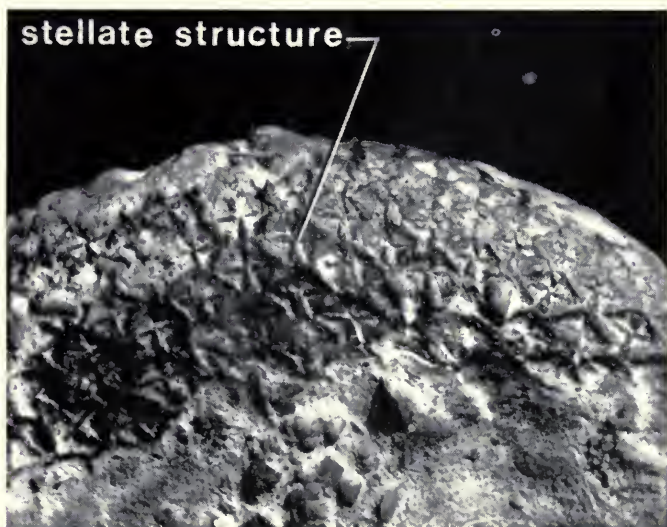


FIG. 29. Stellate structures of English *Ischadites koenigii* from Wenlock Limestone. BMNH P4232 ($\times 2.5$).

Holotype of *Receptaculites formosus* UIX-963 (ISM-11776) (fig. 27c); described by Meek and Worthen, 1870, pp. 22-23; Worthen and Meek, 1875, p. 500, pl. 24, fig. 1; listed by Hansman and Scott, 1967, p. 1026.

Holotype of *Receptaculites pedunculatus* PMYU23286 (fig. 24d); described and illustrated by Twenhofel, 1938, pp. 545-546, pl.

Other material.—FMNH, NYSM, USNM, OS.

Ischadites stellatus (Fagerstrom, 1961). Figure 8k.

Ehlersospongia stellata Fagerstrom, 1961, Jour. Paleontol., **35**, p. 5, pl. 3, figs. 21-23.

Ischadites stellatus Nitecki, 1971, Fieldiana: Geol., **23**, no. 3, pp. 23-30, text figs. 1-3.

?*Receptaculites neptuni* Stauffer, 1915, Canada Geol. Surv. Mem. 34, p. 229.

Receptaculites sp. Fagerstrom, 1961, Jour. Paleontol., **35**, p. 5, pl. 3, fig. 24.

Definition.—Small globose ischaditid with stellate structures consisting of four major and eight alternating smaller ribs.

Discussion.—This species has been recently redescribed as an ischaditid alga (Nitecki, 1971c).

Stratigraphic position.—Silurian (Racine) to Devonian (Formosa Limestone). Reefs only.

Localities.—Greenock Creek, Brant Twp., Bruce County, Ontario (Devonian) and Bridgeport Quarry, Chicago, Illinois (Silurian).

Holotype.—UMMP 36111.

Referred specimen.—FMNH PP 17343.

Ischadites abbottae Nitecki, 1971. Figures 8h, 30.

Ischadites abbottae Nitecki, 1971, Phycologia, **10**, pp. 263-275, 15 text-figs.

Ischadites ohioensis Nitecki, 1969, Fieldiana: Geol., **16**, no. 14, figs. 3A-D.

Receptaculites hemisphericus Whitfield, 1895, Amer. Mus. Nat. Hist., Mem., **1**, pt. 2, pl. 5, fig. 3.

Definition.—Thallus ovoid; main axis apically inflated; sometimes pointed; laterals on upper part of main axis; upper largest laterals clavate; lower laterals thin; lower part of thallus heavily calcified; stellate structures of lower laterals fused; main axis, laterals and stellate structures calcified.

Discussion.—*Ischadites abbottae* has been recently described and illustrated as a dasycladacean alga closely related to *I. hemisphericus* (Hall) and *I. koenigii* Murchison (Nitecki, 1971a).

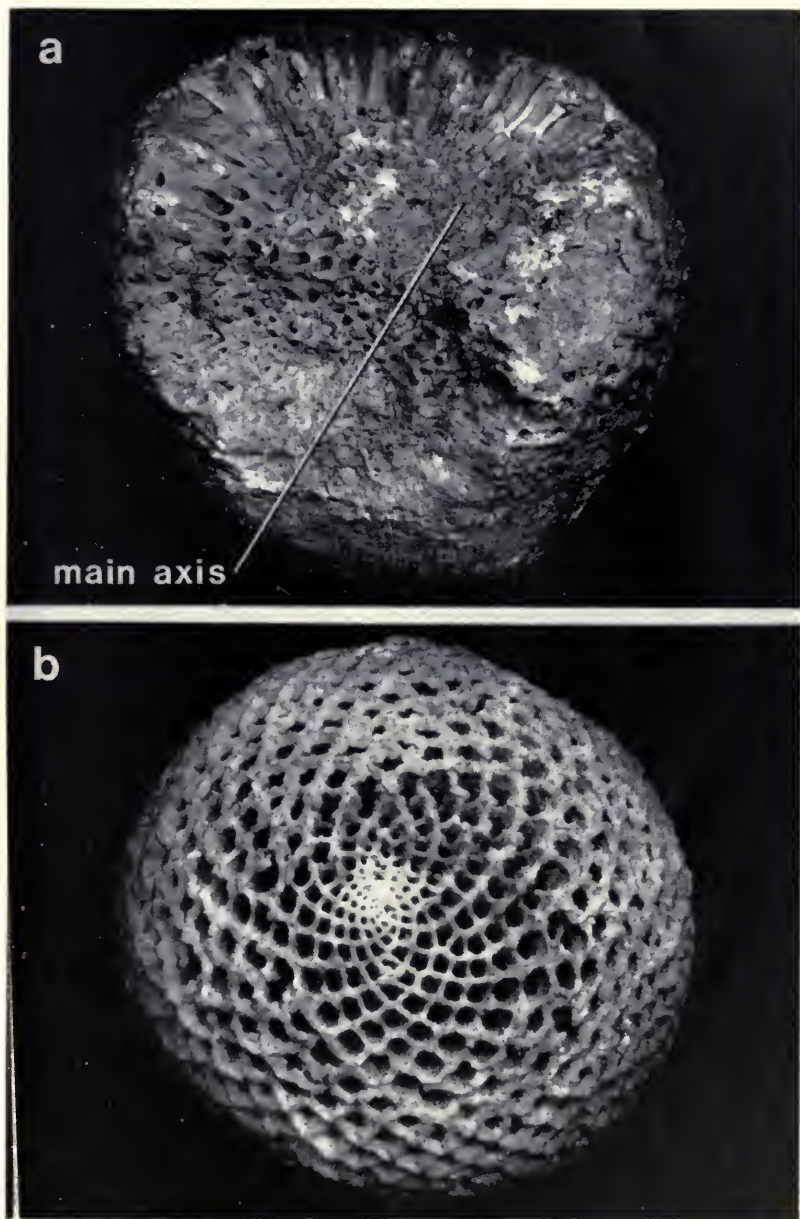


FIG. 30. Racine *Ischadites abbottae* from Chicago, Illinois. **a**, lateral view of buccal main axis FMNH PP 17355 ($\times 1.1$); **b**, apical view FMNH PP17348. (> 1.8)

Stratigraphic position.—Racine Dolomite, Cedarville Limestone, and Edmunds Formation.

Localities.—Bridgeport Quarry, Chicago, Illinois; Schoonmaker Quarry, Wauwatosa, Wisconsin; Racine, Wisconsin; Yellow Springs, Ohio, and Whittings Bay, Edmunds Township, Washington County, Eastport Region, Maine.

Holotype.—FMNH PP 17356.

Other specimens.—FMNH, AMNH, CAS, UWM, USNM.

Ischadites hemisphericus (Hall, 1861). Figures 8g, 10, 31–33.

Ischadites hemisphericus Winchell and Schuchert, 1895, Geol. Minn., 3, pt. 1, p. 66.

Ischadites ohioensis Howell, 1943, Wagner Free Inst. Sci., 18, no. 4, p. 35, 37, 38, pl. figs. 3, 5, 6; *not* Nitecki, 1969, Fieldiana; Geol., 16, no. 14, figs. 3A–D.

Receptaculites hemisphericum Hall, 1861, Rept. Supt. Geol. Surv. Wisc., pp. 16–17; Whitfield, 1882 [1883], Geol. Wisc., 4, pp. 269–270, pl. 13, fig. 4; Head, 1895, Palaeoz. sponges, p. 4; Squires and Hawkins, 1958, Amer. Mus. Nov., no. 1913, pp. 12, 16.

Receptaculites hemisphaericus Hall, 1867, 20th Ann. Rept. State Cab. Nat. Hist., p. 395; Bigsby, 1868, Thesaurus Sil., p. 4; Hall, 1870, 20th Ann. Rept. Regt. N. Y. State Univ., p. 435; Hall, 1871, Geol. Surv. State Wisc. 1859–1863, p. 91; Roemer, 1880, Lethaea Palaeoz., I Theil, p. 289.

Receptaculites hemisphericus Hall, 1862, Rept. Geol. Surv. Wisc., 1, p. 429; Hall, 1863, 16th. Ann. Rept. N. Y. State Cab. Nat. Hist., p. 68; Hall, 1863. Trans. Albany Inst. (adv. sheets), 4, p. 31; Hall, 1864, Trans. Albany Inst., 4, p. 225; Hall and Whitfield, 1875, Geol. Surv. Ohio Rept., 2, part 2, p. 123; S. A. Miller, 1877, Amer. Palaeoz. foss., p. 44; Chamberlin, 1878, Geol. Wisc., 2, pp. 372, 384; Hall, 1879, 28th Ann. Rept. N. Y. State Mus., p. 103; Hall, 1882, 11th Ann. Rept. Geol. Surv. Ind., p. 222; Whitfield, 1882 [1883], Geol. Wisc., 4, pl. 13, fig. 4, p. 350; Lesley, 1889, Penn. Geol. Surv. Rept. P4, 2, pp. 854, 855; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 163; Whitfield, 1895, Mem. Amer. Mus. Nat. Hist., 1, pt. 2, pp. 46, 47 *partim*, pl. 5, fig. 4 [not 3]; Kindle, 1898, 22nd Rept. Ind. Geol. Surv., p. 418; Whitfield, 1899, Ann. N. Y. Acad. Sci., 12, no. 8, p. 145; Whitfield and Hovey, 1899, Bull. Amer. Mus. Nat. Hist., 11, pp. 78–79; Grabau and Shimer, 1909, N. Amer. Index fossils, 1, p. 19; Teller, 1911, Bull. Wisc. Nat. Hist. Soc., 9, no. 4, p. 187; Bassler, 1915, Bull. U. S. Nat. Mus. 92, pp. 1,096–1,097; Twenhofel, 1938, Trans. Wisc. Acad. Sci. Arts. Letters, 31, p. 546; Ball and Greacen, 1946, Chgo. Acad. Sci. Sp. Publ. 7, p. 14; Greacen and Ball, 1946, Sil. Invert. fossils, p. 11; Peck and McFarland, 1954, Jour. Paleontol., 28, no. 3, p. 298.

Receptaculites ohioensis Hall and Whitfield, 1875, Rept. Geol. Surv. Ohio, 2, part 2, p. 123, pl. 6, fig. 1; S. A. Miller, 1877, Amer. Palaeoz. fossils, p. 44; Roemer, 1880, Lethaea Palaeoz., I Theil, p. 290; Hinde, 1884, Quart. Jour. Geol. Soc. London, 40, p. 837; Lesley, 1889, Geol. Surv. Penn. Rept. P4,

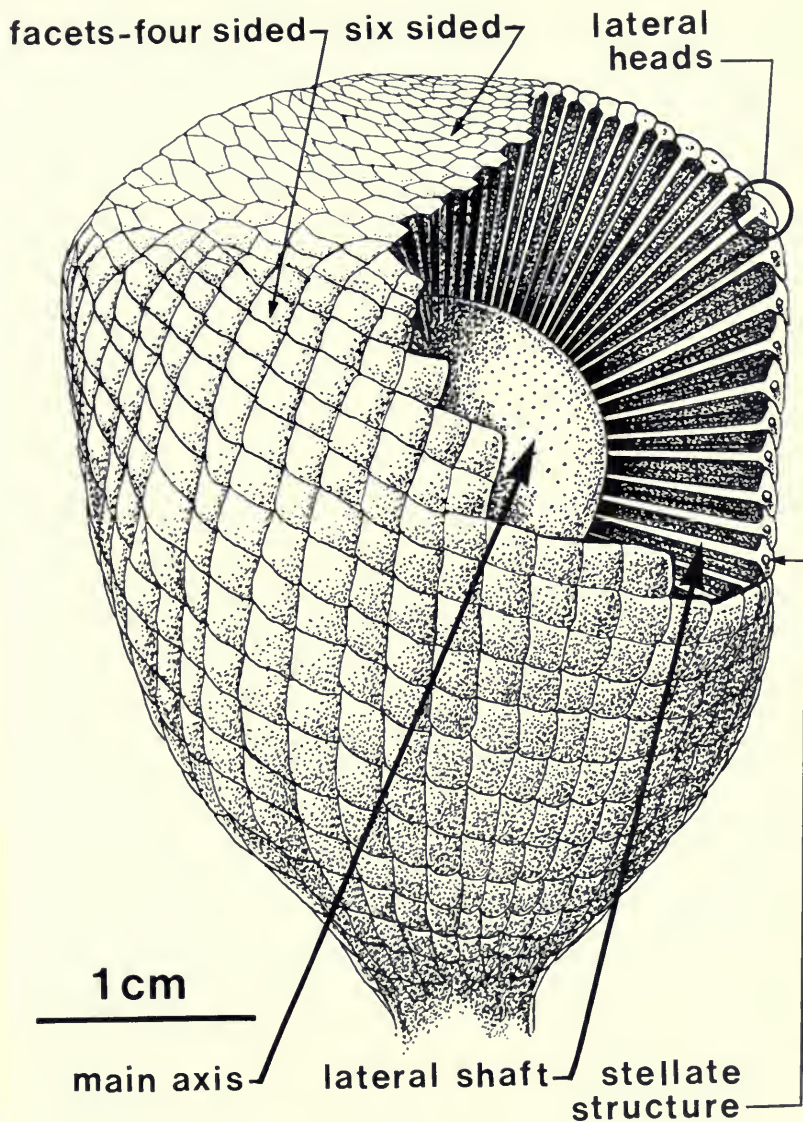


FIG. 31. Reconstruction of *Ischadites hemisphericus*.

2, p. 854, text fig.; S. A. Miller, 1889, N. Amer. Geol. Palaeontol., p. 164; Head, 1895, Palaeoz. Sponges, p. 4; Winchell and Schuchert, 1895, Geol. Minn., 3, part 1, p. 65; Miller and Gurley, 1896, Ill. State Mus. Bull., 11, p. 49; Whitfield, 1899, Ann. N. Y. Acad. Sci., 12, no. 8, p. 145; Whitfield and Hovey, 1899, Bull. Amer. Mus. Nat. Hist., 11, pp. 78-79; Grabau and Shimer, 1909, N. Amer. Index fossils, 1, p. 19, fig. 29; Bassler, 1915, Bull. U. S. Nat. Mus. 92, p. 1,097; Morningstar, 1924, Ohio Jour. Sci., 24, no. 1, p. 59; Peck and McFarland, 1954, Jour. Paleontol., 28, no. 3, pp. 299, 300; Squires and Hawkins, 1958, Amer. Mus. Nov., no. 1913, p. 16.

Definition.—Medium-size ischaditids; thallus distinctly globular, often barrel-shaped; sometimes flattened, rarely discoidal; all lateral shafts thin, terminally rapidly dilated; heads of upper laterals large with stellate structures weakly calcified, or absent; heads of lower laterals small, stellate structures well calcified forming rigid framework; calcification strongest on stellate structures of lower laterals and on distal ends of upper laterals, weak on proximal parts of lower laterals; apical facets commonly six-sided; lower facets mostly rhombohedral, occasionally six-sided.

Description.—**THALLUS:** The description of the species is based upon mostly incomplete specimens with generally the lowermost parts missing (figs. 32, 33). The thallus is ovoid, often barrel-like, sometimes basally pointed, and rarely discoidal. There are three kinds of body shapes preserved: flat apical region of incomplete specimens (fig. 32b), half specimens particularly from the Ohio region (fig. 32a), and the most complete fossils from the Chicago area (fig. 31). The thallus is clearly differentiated into two parts. The upper part has the lateral heads large and the stellate structures seldom calcified; the lower part of the thallus has small thin heads and well-calcified stellate structures. The incompleteness of the preservation of thalli is such that no average body size can be estimated. When attempts of estimations are made, *I. hemisphericus* is assessed as being broader than tall. The tallest specimen is 5.46 cm. high; the widest, 4.63 cm. wide; the shortest, 1.40 cm.; and the smallest 1.90 cm. across.

FACETS: The tops of most specimens consist of impressions of lateral heads now preserved as cups. Small holes inside facets are cross-sections of the termini of laterals. Sometimes crystals grow in openings and small projections result. The shapes of facets vary from specimen to specimen, and within single fossils. The upper facets are generally irregular, on occasion extremely well formed. Except at the very top of the thallus, they tend to be six-sided but the lowermost are generally four-sided. The shape of most facets is

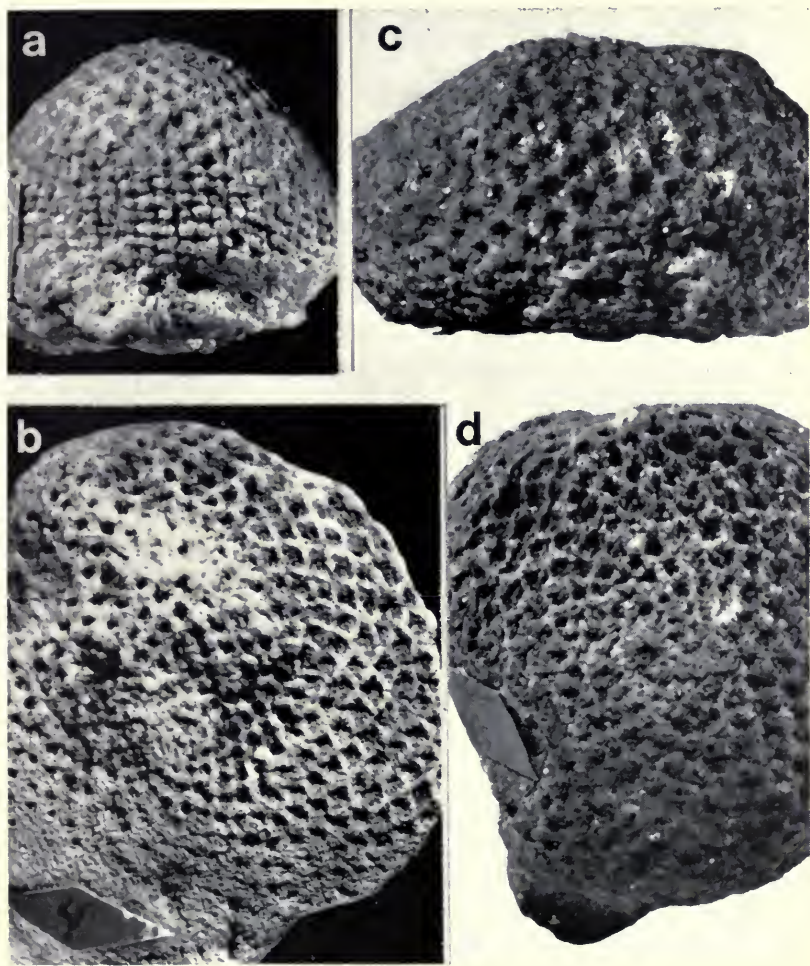


FIG. 32. *Ischadites hemisphericus*. a, lateral view, AMNH 1975 ($\times 2.3$); b, apical view, holotype, AMNH 1974 ($\times 1.7$); c, lateral view, OS 14905 ($\times 2.5$); d, apical view, UCMP 34212. ($\times 2.2$)

somewhat distorted by the presence of large crystals of dolomite that form their edges. The largest facets are found somewhat above the middle of the thallus. The edges of facet walls form sinusoidal lines radiating from the apex, a characteristic of most receptaculitids.

LATERALS: The sizes of facets correspond with the sizes of laterals and hence the largest laterals are found somewhat above the equatorial region. All laterals are pointing toward the upper part of the

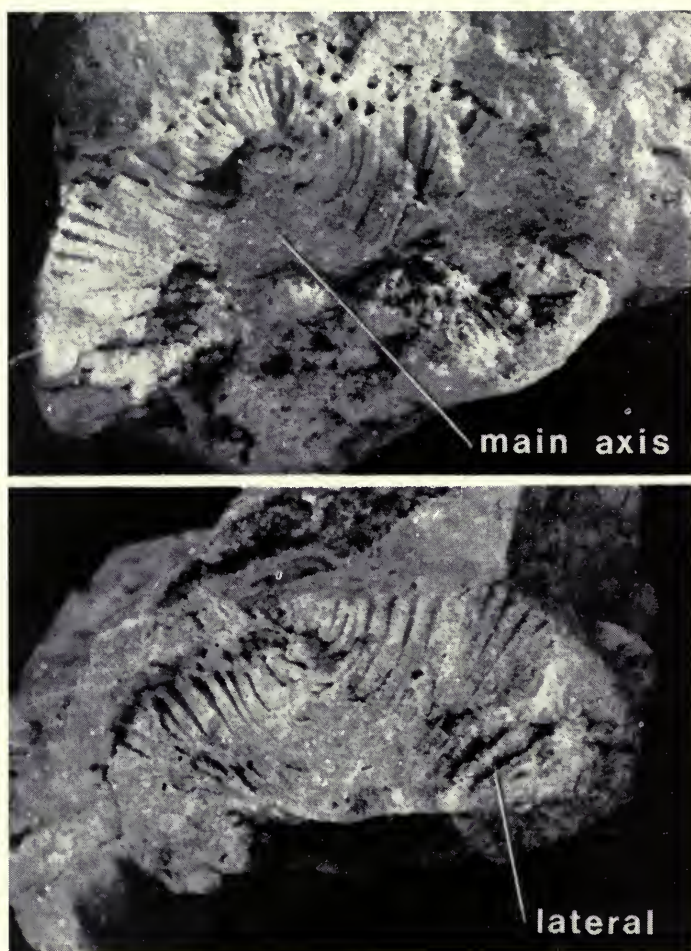


FIG. 33. Lateral branches of *Ischadites hemisphericus*. USNM 93302. ($\times 2.2$).

main axis and the main axis is somewhat pointed apically. Laterals form heads which in the upper part of the thallus are round and similar to cyclocrinitid heads; the lower smaller heads are distinctly flattened.

STELLATE STRUCTURES: Faint stellate structures are preserved on a few upper facets. Well-preserved stellate structures are observed on the lower part of the thallus. Below the equatorial region the characteristic horizontal and vertical lines left after the dissolution of stellate structures are observed. It cannot be determined with cer-

tainty which ribs are above and which are below. Possibly they were at the same plane. The orientation of the ribs of stellate structures is exactly parallel and perpendicular to the longest axis of the plant. The number of ribs is four or sometimes less, often the exact number cannot be determined. It seems that lower horizontal ribs of stellate structures were more calcified than the vertical elements, and the vertical may have been more commonly outer.

GROWTH: The growth pattern of *I. hemisphericus* is characteristically that of most ischaditids. The lateral heads farther away from the growing point are the largest and are somewhat above the middle part of the thallus. New laterals are added at random and increase the number of branches in apparent whorls. The stellate structures of the largest specimens of *I. hemisphericus* are fused in lower parts of the thallus. The heads of the upper branches are bigger and hence the facets are also bigger. The process of aging in this species is very similar to the aging in *Ischadites abbottae* (Nitecki, 1971a).

CALCIFICATION: The calcification is not uniform throughout the thallus. The bases of lateral heads are calcified heavily in the upper part of the organism, and stellate structures are heavily calcified in the lower parts.

Relationship.—The relationship of *I. koenigii* is closest to *I. abbottae* from which it differs in the size and shape of upper laterals. When poor specimens of both species are studied, the individuals are hard to differentiate. *I. hemisphericus* differs from *I. koenigii* in possession of two distinct sets of lateral heads, in more heavily fused lower stellate structures, and in the lack of differentiation of branches other than differences in their lateral heads. The body shape of *I. hemisphericus* appears less variable than that of *I. koenigii*.

Gametangia.—Gametangia are not preserved, and are assumed to have been carried within the heads of upper branches.

Stratigraphic position.—The Illinois and Wisconsin fossils are from Racine Formation. The Ohio material is labelled either Niagaran or Cedarville Formation.

Locality.—Bridgeport Quarry in Chicago, Illinois; Racine and Naukeshia, Wisconsin; Dayton, Wilmington (Moody Quarry), Durbin (Jenkins Quarry), Yellow Springs, Kenton and Cedarville, Ohio. No detailed information on the Ohio localities is available.

Type specimens of *Ischadites hemisphericus*.—The whereabouts of the type specimens of *Ischadites hemisphericus* has been beset with confusion. American Museum of Natural History, Museum of

Paleontology of the University of California at Berkeley, and Orton Museum of the Ohio State University have each claimed the possession of the primary types. Whitfield and Hovey (1899) stated in the catalogue of type specimens in the paleontological collections of the Geological Department of the American Museum of Natural History that the types of *hemisphericus* and *ohioensis* are housed in that museum. Whitfield (1899) published a list of types used in his paleontological work in which he indicated the University of California at Berkeley as depository of *R. hemisphericus* and Ohio State College as depository of *R. ohioensis*. Teller (1911) wrote that the type of *hemisphericus* was collected in Wisconsin and is now stored in the American Museum. Morningstar (1924) in the catalogue of types in the Geological Museum at the Ohio State University claimed that a "paratype" of *ohioensis* from Yellow Springs, Ohio is housed in that museum. Peck and McFarland (1954) indicated that the holotype of *ohioensis* is housed at the University of California, Museum of Paleontology. However, the holotype of *hemisphericus*, although stated by Whitfield to be in California, has never been received by that institution. Finally, in the catalogue of type sponges of the Department of Paleontology of the American Museum Squires and Hawkins (1958) list "syntypes" of *hemisphericus* and *ohioensis* as housed in their collections. They also clarify the status of types in California.

The examination of all these specimens reveals that all were used for the original descriptions, and even illustrations, and therefore all are equally important for our understanding of the original concepts of *hemisphericus* and *ohioensis*. Whitfield (1895) for the first time illustrated two "types" of Hall, but did not select the holotype. Because *hemisphericus* carries the chronological priority over *ohioensis*, the holotype must be selected from among specimens illustrated as *hemisphericus*. This is unfortunate, because the "types" of *ohioensis* are better preserved and therefore show more morphological characters.

Holotype.—Here designated (fig. 32b) the specimen figured by Whitfield, 1895, pl. 5, fig. 4. [not fig. 3], AMNH 1974 with number 4 on a green diamond sticker.

Referred specimens.—AMNH 1974/1, AMNH 2889, AMNH 1975 (fig. 32a), OS 14905 (fig. 32c), UCMP 34212 (fig. 32d), PU 301.

Other specimens.—Numerous fossils in USNM, CAS, FMNH, UCC, PU, UWM.

Ischadites burntensis (Shrock and Twenhofel, 1939). Figures 8i, 34, 35.

Goldsonia burntensis Shrock and Twenhofel, 1939, Jour. Paleontol., **13**, p. 247, pl. 27, figs. 2-4; Williams, 1963, Canad. Geol. Surv. Paper 63-36, p. 15.

Ischadites (in part) Byrnes, 1968, Lethaia, **1**, p. 368.

Definition.—Medium (?) size ischaditid; laterals clavate, distally expanding; lateral heads of double set of stellate structures in one plane.

Description.—Only two slides are available for study. The cross-section through laterals shows faint, circular, travertine-like markings (fig. 35). These are devoid of any organic structure, are calcitic, and do not appear to be original. The calcite of these structures is not related to any structure, nor to any crystallographic pattern. Also present are faint radial concentric lines. These are discontinuous, unrelated and therefore considered inorganic and of a secondary origin.

The longitudinal section (fig. 34) is also devoid of any organic details; it is made up of secondary post-depositional calcite. The calcite crystals have no organic structures, however, they are peculiar and difficult to interpret. No central cores are observed in either of the two slides. Matrix consists of a fine-grained impure limestone, an argillaceous calcilutite.

The slides show cross-sections through laterals of a distinct ischaditid. The laterals are clavate and expand gently outward. The laterals terminate with a head (not shown in figure) that consists of a double stellate structure in one plane. Whether this plane is horizontal or vertical cannot be determined, because the orientation of the fossil is unknown. They are probably vertical elements.

Discussion.—Shrock and Twenhofel (1939) considered this fossil to be a calcareous red alga and the inorganic structures within "stems" were assumed to be growth lines. Byrnes (1968) correctly placed *Goldsonia* in the synonymy with *Ischadites*. The Shrock and Twenhofel stems are lateral branches, and their "mushroom-like structures" on the summits of stems are lateral heads.

The shape of the lateral shaft is similar to the shape of the mature aateral of *I. abbottae*. *I. burntensis* differs from *abbottae* in possession of a double set of stellate structures which can be compared with the more complicated elements of the double set of ribs present in *I. stellatus*.



FIG. 34. Longitudinal section through the laterals of *Ischadites burntensis*. Lateral heads not preserved. PM 25597. ($\times 6.5$)

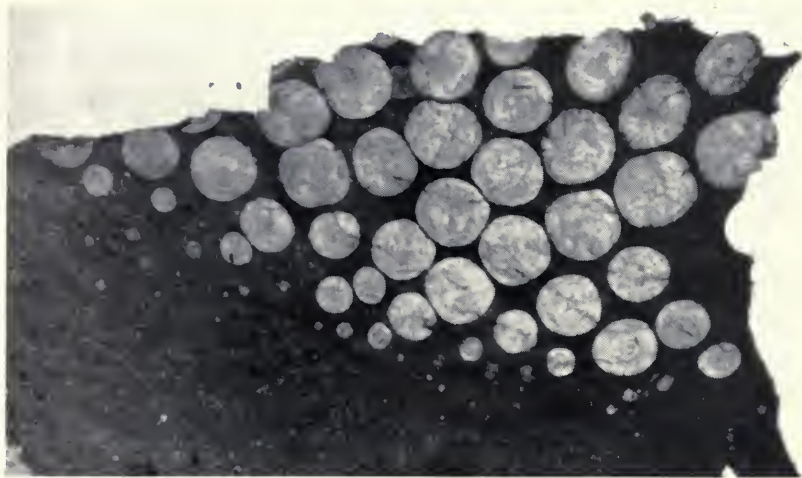


FIG. 35. Cross-section through the laterals of *Ischadites burntensis*, PM 25597 ($\times 6.5$).

Stratigraphic position.—Pike Arm Formation. Black argillite. Williams (1963) considers Pike Arm Formation to be part of Goldson Formation.

Locality.—Burnt Island in Goldson Arm, New World Island, Newfoundland.

Holotype.—Slide PM 25597 (fig. 34), longitudinal section through laterals of holotype (Shrock and Twenhofel, 1939, pl. 27, fig. 3).

Referred specimen.—Slide same number (fig. 35), cross-section through laterals of second specimen (Shrock and Twenhofel, 1939, pl. 27, fig. 2); the specimen figured by Shrock and Twenhofel, 1939, pl. 27, fig. 4, not available for examination.

Ischadites subturbinatus (Hall, 1863). Figures 6, 7, 8f, 36, 37, 38.

Ischadites koenigii Hinde, 1884, Quart. Jour. Geol. Soc. London, **40**, pp. 836, 837.

Ischadites cf. koenigii Twenhofel, 1928, Geol. Surv. Canada Mem. 154, pp. 83, 103.

Ischadites subturbinatus Winchell and Schuchert, 1895, Geol. Minn., **3**, pt. 1, pp. 65, 66; Bassler, 1915, Bull. U. S. Nat. Mus., **92**, **1**, p. 670.

Receptaculites subturbinatus Hall, 1863, Trans. Albany Inst. Adv. sheets, pp. 30–31; Hall, 1863, 16th Ann. Rept. N. Y. State Cab. Nat. Hist., p. 68; Hall, 1864, Trans. Albany Inst., **4**, pp. 224–225; Bigsby, 1868, Thesaurus Sil., p. 4; Miller, 1877, Amer. Palaeoz. fossils, p. 44; Hall, 1879, 28th Ann. Rept.

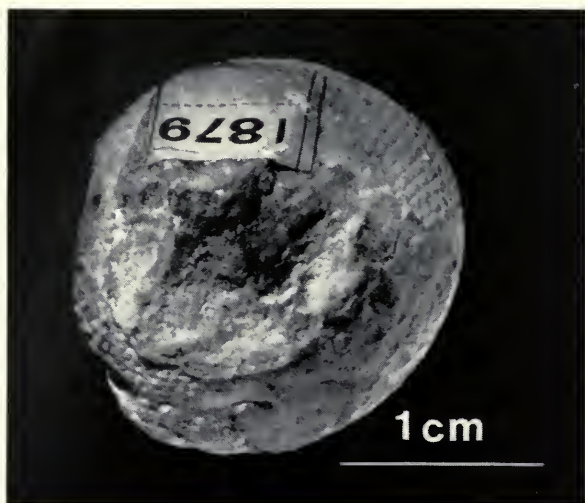


FIG. 36. Holotype of *Ischadites subturbinatus*. AMNH 1879.

N. Y. State Mus. Nat. Hist., p. 103, pl. 3, figs. 1-3; Roemer, 1880, *Lethaea palaeoz.*, I Theil., p. 290; Hall, 1882, 11th Ann. Rept. Geol. Surv. Ind., pp. 221-222, pl. 2, figs. 1-3; Hinde, 1884, *Quart. Jour. Geol. Soc. London*, **40**, pp. 836, 837; Lesley, 1889, *Geol. Surv. Penn.*, Rept. P4, **2**, p. 855, 3 text-figs.; S. A. Miller, 1889, *N. Amer. Geol. Palaeontol.*, p. 164; Head, 1895, *Palaeoz. sponges*, p. 2; Winchell and Schuchert, 1895, *Geol. Minn.*, **3**, part 1, pp. 65, 66; Miller and Gurley, 1896, *Ill. State Mus. Bull.* **11**, p. 49; Kindle, 1898, 22nd Rept. Ind. Geol. Surv., p. 418; Whitfield and Hovey, 1899, *Bull. Amer. Mus. Nat. Hist.*, **11**, pp. 78-79; Bassler, 1915, *Bull. U. S. Nat. Mus.*, **92**, p. 670; Squires and Hawkins, 1958, *Amer. Mus. Nov.*, no. 1913, p. 21.

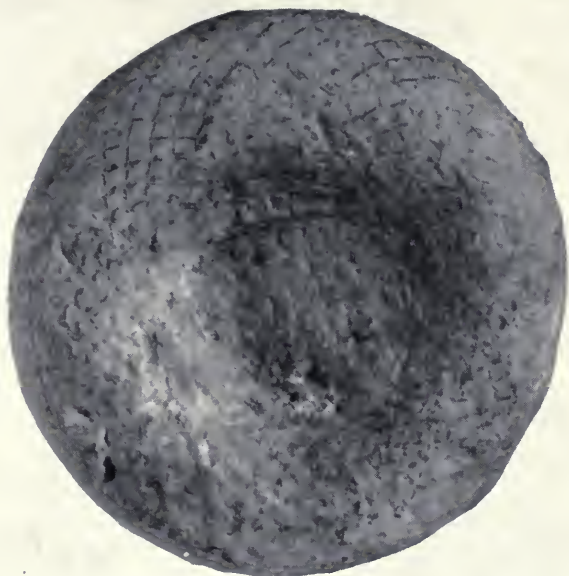
Definition.—Small ischaditids; thallus discoidal; all laterals thin, enlarged below heads, terminating with rhomboidal plates, overlapping in lower parts of thallus; four ribs of stellate structures in one plane; lateral shafts, stellate structures and sometimes plates of lateral heads calcified.

Description.—**THALLUS:** The shape of thalli vary from the most common discoidal to the rare pointed oval. Upper part of thallus is often convex, and the lower mostly concave. Conical and flat top specimens are observed. Thallus always broader than high. The attachment scar is sometimes observed (fig. 6).

PLATES: The plates are sometimes preserved distributed throughout the thallus. They are never six-sided, are very regular, distinctly rhomboidal and are overlapping in the lower part of the thallus.

STELLATE STRUCTURES: Stellate structures consist of four ribs in one plane and are more pronounced, but not exclusive in the lower

a



b

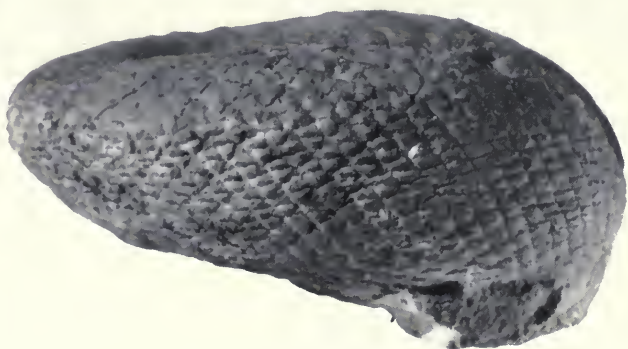


FIG. 37. *Ischadites subturbinatus*. **a**, apical view, FMNH UC 10822 ($\times 2.2$);
b lateral view, FMNH UC2575 ($\times 2.7$).

part of the body. The facets are now preserved with a central relatively large knob and four ribs of stellate structures projecting toward each corner of facet. Hall's figure 2 (1879, and subsequent) appears to have been drawn inaccurately, probably because it was based upon a poorly preserved specimen.

LATERALS: Laterals are attached to the bulbous upper part of the main axis. Laterals are long and thin (fig. 7) throughout and enlarged just below the stellate structures. Although the laterals are always borne in spiral they are sometimes distributed unequally on the same plant (figs. 6, 7). Thus the density of laterals per given area of the body surface is meaningless as a species character.

MAIN AXIS: Main axis is uncalcified, and is assumed to have been apically bulbous.

CALCIFICATION: Lateral shafts are weakly calcified, but the lateral heads particularly at their bases are strongly calcified. Stellate structures are moderately calcified in the lower parts of the thallus. Edges of facets are calcified strongly and thus facets are pronounced.

PRESERVATION: Many specimens are now replaced with pyrite. The lower part of the thallus is seldom observed. The flattened specimens are common, the preservation possibly due to the compaction of the shaly sediments. Stellate structures are sometimes displaced in the periphery of the thallus.

Measurements.—Diameter of the largest thallus: 3.55 cm., smallest: 1.90 cm., tallest (incomplete): 1.80 cm., smallest (incomplete): 0.63 cm.; longest lateral: 1.11 cm. long; greatest number of laterals in spiral: 52.

Relationship.—*Ischadites subturbinatus* is closely related to *I. hemisphericus*, *koenigii*, and the Ordovician *I. iowensis*. *I. hemisphericus* and *I. subturbinatus* have very similar stellate structures in one plane, and often their body shapes are similar. However, *I. subturbinatus* has always four-sided facets (fig. 37a) and its stellate structures are developed throughout the thallus, not only in the lower part as in *hemisphericus*. However, the shapes of their thalli generally differ. Most *subturbinatus* are collapsed discs (fig. 37b), while most *hemisphericus* are barrel-shaped. The lateral of *subturbinatus* is bulging below the head, a unique structure in the species. In *I. koenigii* the size of facets seldom changes within single individuals, and they are the same size throughout the thallus. *I. koenigii* and *I. subturbinatus* possess very regular four-ribbed stellate struc-

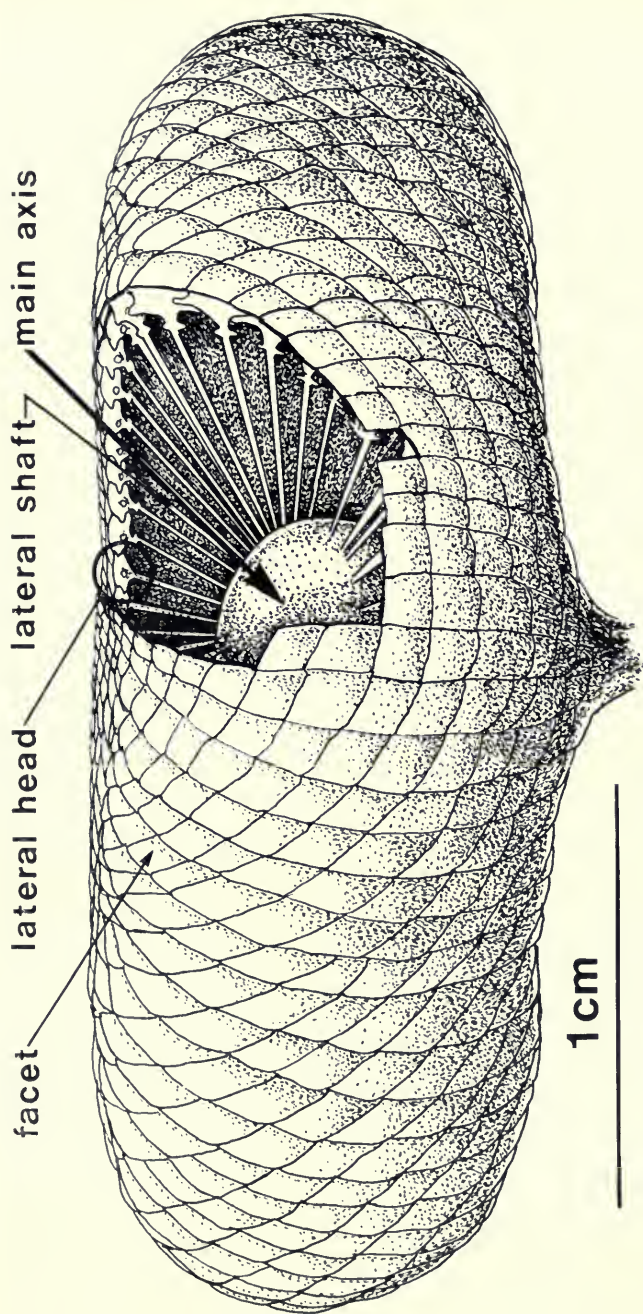


FIG. 38. Reconstruction of *Ischadites subtrubidatus*.

tures. The holotype of *I. iowensis*, a North American Ordovician ischaditid, is of approximately the same size and body shape as many specimens of *subturbيناتus* from Indiana.

The main difference between *I. subturbيناتus* and most other ischaditids is the distinct flattening of the body of *I. subturbيناتus* which may be non-ecological, and the presence of enlargement of the lateral shaft below the lateral head.

Stratigraphic position.—Waldron Shale (Indiana). Jupiter River Formation, Zone 1 (Anticosti Island). The Anticosti specimens came from thin-bedded limestone. The Indiana fossils are from shale or from shaly limestone facies.

Locality.—Hall (1879) states that all his specimens came from a single locality on Conn's Creek in town of Waldron, Decatur County, Indiana. In addition, the specimens have been collected from Harts-ville, and Blue Ridge Quarry, Indiana, and from Anticosti Island, Canada.

Holotype.—Specimen listed by Whitfield and Hovey (1899) and Squires and Hawkins (1958), AMNH 1879 (fig. 36). This specimen, however, does not correspond exactly with the Hall (1879 and subsequent) figure. It is possible that the figure was composite, but other figures of Hall (1879) correspond well with available types. AMNH 1879 has characteristic markings used by Hall, therefore, there is no doubt that it is Hall's original specimen.

Referred specimens.—FMNH UC51849 as figured by Hall (1879 and subsequent, pl. 3, fig. 2); PM22760 as described by Twenhofel, 1928, pp. 83, 103.

Other specimens.—Numerous specimens—FMNH, NYSM, and USNM.

***Ischadites planoconvexus* n. sp. Figures 8e, 39–41.**

Receptaculites Clarke, 1920, N. Y. State Mus. Bull. 239, 240, pl. between pp. 24, 25.

Definition.—Thallus plano-convex, often concavo-convex, apically convex, basally flat or concave; young thallus sometimes globular with elongate apex; very top of thallus in adult not preserved; laterals very thin and long, distributed very densely throughout the main axis, occasionally calcified; facets gradually increasing in size; stellate structures mostly four-ribbed, always calcified.

Description.—THALLUS: The adult thallus is very flattened (fig. 39), disc-like with the apical side almost always convex and the basal

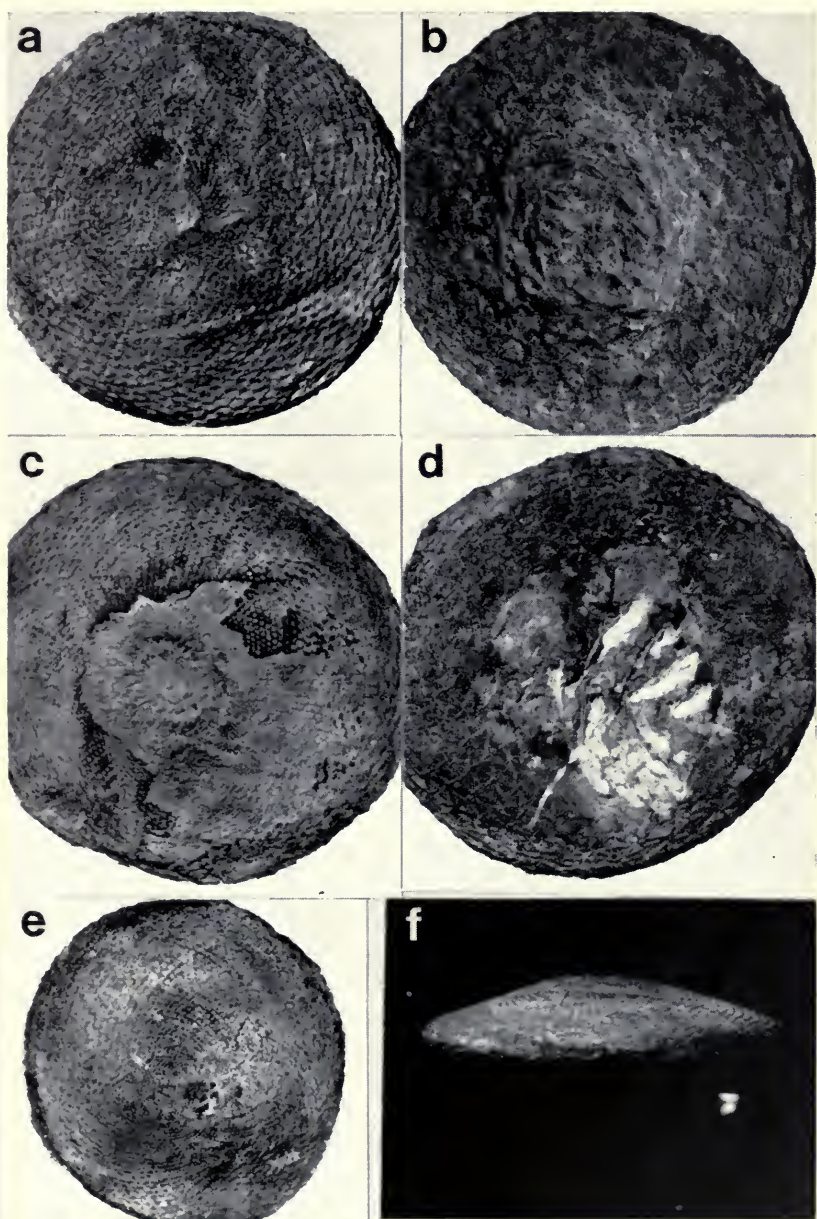


FIG. 39. Three mature specimens of *Ischadites planoconvexus*. **a**, apical and **b** basal view of holotype, FMNH PP 17737; **c**, apical and **d**, basal view, FMNH PP 17738; **e**, apical and **f**, lateral view, FMNH PP 17739. (All $\times 1.5$)

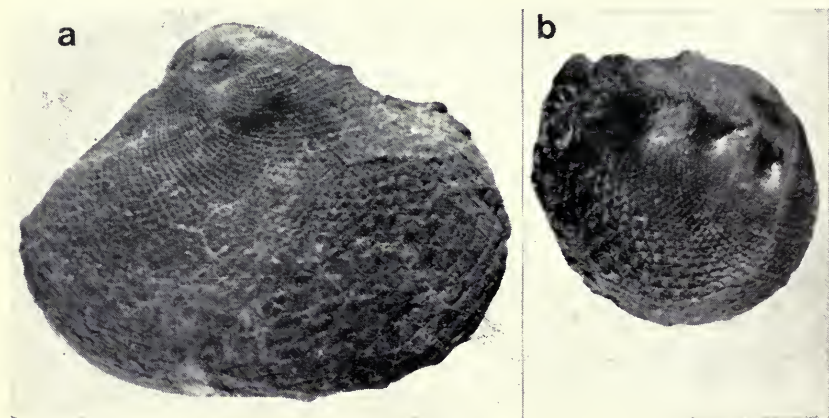


FIG. 40. Oblique view of *Ischadites planoconvexus*. **a**, single apex of immature specimen, FMNH PP 17740; **b**, multiple apex of immature specimen, FMNH PP 17741 (All $\times 3.3$).

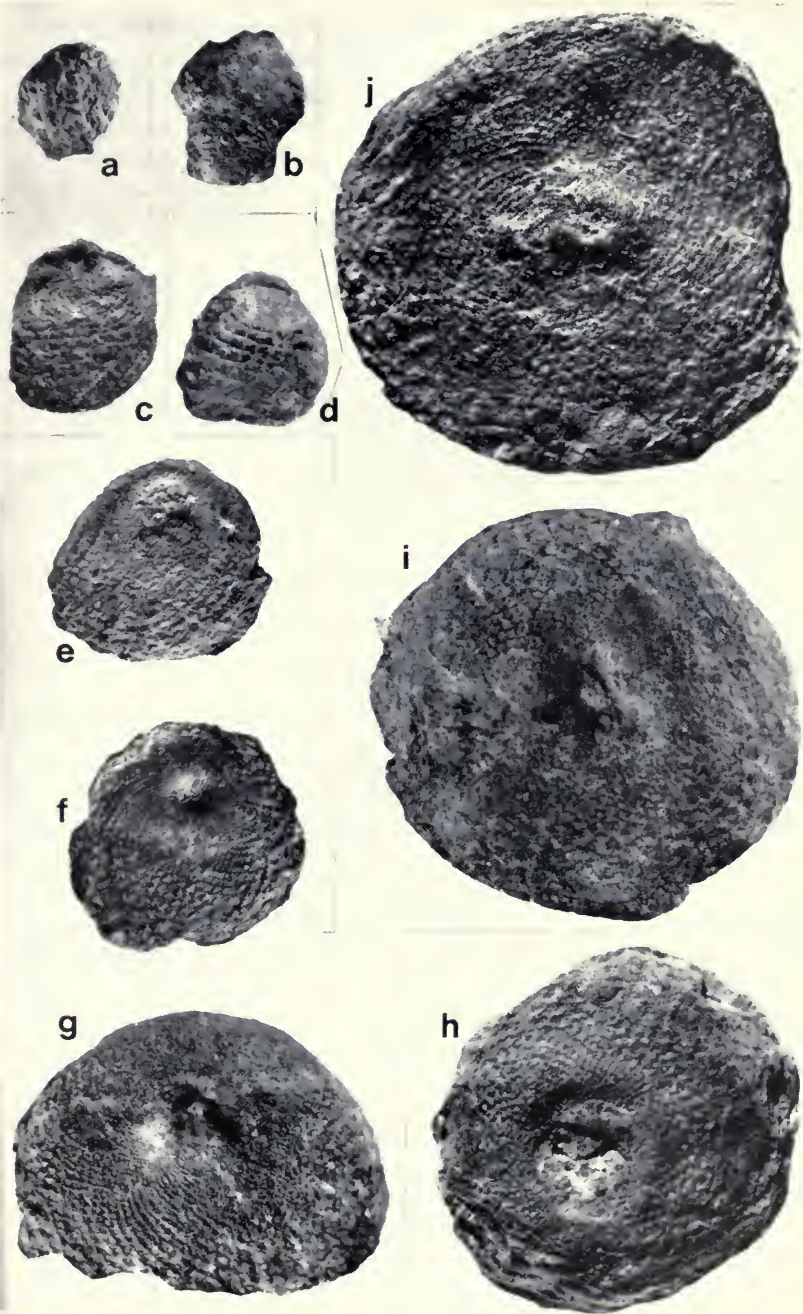
side mostly concave or rarely flat. No adult thallus of other shape has been observed. Almost all specimens are flattened apically and seldom has lateral compression been observed. In adult forms the uppermost part of the body (the growing point) is not preserved.

MAIN AXIS: Main axis is not preserved, however, from the general shape of the thallus, and by comparison with other known forms the shape of the main axis is assumed to have been apically bulbous.

LATERALS: Laterals, as in other members of the group, are arranged in spiral. However, the spiral is difficult to trace because of the poor preservation of the exterior of the thallus, absence of the uppermost part of the thallus, and a large number of laterals packed together. Laterals are extremely long, thin structures terminating with lateral heads. The longest laterals observed are 0.9 cm. and appear to be at least one-third of the greatest dimension of the plant. Exact measurements cannot be secured. The upper laterals are considerably shorter.

LATERAL HEADS: Lateral heads consist of facets and stellate structures. The plates are seldom observed. The facets are rhom-

FIG. 41. Growth stages of *Ischadites planoconvexus* arranged in alphabetical order. **a-d**, lateral view; **e, f**, oblique view; **g-j**, apical view. **a**, FMNH PP 17742 ($\times 5.3$); **b**, FMNH PP 17743 ($\times 5.2$); **c**, FMNH PP 17744 ($\times 4.6$); **d**, FMNH PP 17745 ($\times 5.5$); **e**, FMNH PP 17746 ($\times 3.2$); **f**, FMNH PP 17747 ($\times 4.0$); **g**, FMNH PP 17748 ($\times 5.6$); **h**, FMNH PP 17751 ($\times 7.3$); **i**, FMNH PP 17750 ($\times 5.6$); **j**, FMNH PP 17749 ($\times 6.2$).



boidal in the lower part and underside of the thallus (fig. 39b). Bases of facets are calcified and therefore are shallow. The apical facets are small and poorly preserved. In the lower part of the body they gradually expand. The oldest, bottom facets are the largest, best formed, very regular in shape, and distinctly rhomboidal.

Stellate structures consist almost exclusively of four ribs arranged almost in one plane. Those in the lower parts of the thallus are regular and form parallel lines on the exterior.

Plates appear thin, are very rarely preserved, therefore were probably weakly calcified.

GROWTH: Young thalli are either globular or very little flattened. In immature specimens an elongate single or sometimes multiple apex forms (fig. 40). The disc shape of the thallus is, however, rapidly reached when the specimens became apically slightly convex and basally somewhat concave (fig. 41), and the protruding apex disappears.

Relationship.—The individuals of this species have the most flattened thallus of any known ischaditid. This could represent a sedimentary compaction, particularly since the matrix is a finely laminated claystone. However, few other fossils associated with *I. planoconvexus* are flattened, and the shapes of brachiopods and ostracods appear unchanged. Furthermore, *I. subturbinatus* from the shales of Waldron Formation is not as much compressed. Therefore, the body shape is considered a species character. *I. koenigii* from England, but not from North America, have been observed flattened. British specimens also seem to have a greater density of laterals. No other North American Silurian ischaditid is known with such density of laterals. Such density is common among Ordovician species.

Stratigraphic position.—Willowvale Shale; about 15 ft. below the upper fossil iron ore.

Locality.—Small brook behind J. B. Weed's farm, one mile southwest of Verona Station, Oneida County, New York.

Holotype.—FMNH PP 17737

Referred specimens.—Clarke, 1920, N.Y. State Mus. Bull. 239, pl. on p. 24, NYSM 12760.

Other material.—Numerous specimens NYSM, FMNH, MCZ.

Ischadites prismaticus n. sp. Figures 8j, 42, 43.

Definition.—Large ischaditid, with distal parts of laterals modified into elongate rays; in younger specimens main axis pointed;

stellate structures four-ribbed in bases of rays; calcification of rays heavy, of proximal parts of laterals moderate, and of main axis and stellate structures very weak.

Description.—**THALLUS:** In small specimens the thallus is typically ischaditid, mainly a somewhat compressed globe; in older organisms the pronounced flattening is observed. The largest thallus must have been at least 4.5 cm. across.

MAIN AXIS: Main axis in younger specimens is pointed; in older the top of main axis flattens out and becomes more bulbous-like (fig. 42).

LATERALS: The laterals consists of two distinct parts (fig. 8j). The proximal part of the lateral is typically ischaditid (that is, thin) and terminating with stellate structures. The distal part of laterals is modified into a generally four-sided ray that projects above the stellate structures. No rounded head forms, as in other species. The exact length of rays cannot be determined because the ends of rays are now broken off. The maximum proximal part measured is 0.92 cm. long. The maximum distal part is 0.66 cm. long. The largest dimension across the ray is 0.40 cm. The ray is generally four sided, however five and six-sided rays are observed (fig. 43). The shaft of the lateral is somewhat protruding towards the interior of the ray. The shaft is now represented by a hole in the bottom of the ray. This is not in the middle of the facet but always proximal with relation to the center of the organism. The bottoms of rays are not always at the same level within the thallus.

All laterals point toward the upper part of the main axis indicating that they were arranged around the more or less bulbous part.

In the young specimens the ray is much shorter and the upper laterals are somewhat bent.

The lower parts of rays often do not touch and produce a double wall. In areas further away from the shaft the single common wall forms.

STELLATE STRUCTURES: The stellate structures are present just above the floor of facets of rays. The stellate structures are extremely weakly calcified, and appear to consist of four ribs.

FACETS: Facets are formed by edges of rays and are commonly four-sided, however, six-sided as well as five-sided are present (fig. 43).

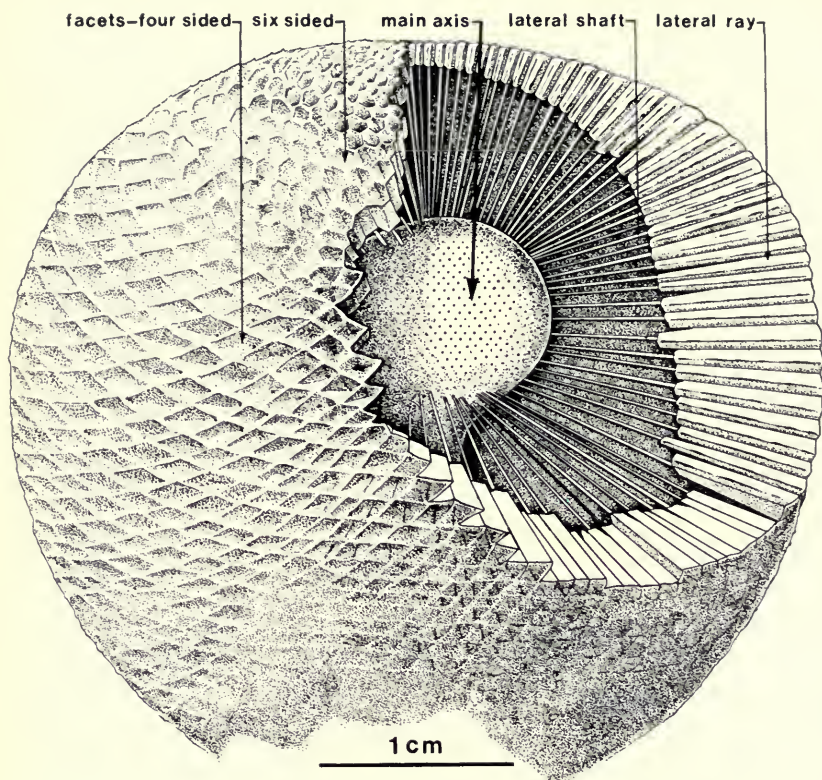


FIG. 42. Diagrammatic reconstruction of thallus of *Ischadites prismaticus*.

CALCIFICATION: The rays are heavily calcified and form the most conspicuous elements of the plant. The shaft of proximal parts of laterals must have been calcified. The main axis is observed in younger specimens which therefore is calcified, although weakly. The least calcified elements are those of stellate structures. The lowermost part of the body was not calcified at all, and hence is not preserved.

Gametangia.—The gametangia are assumed to have been carried in the lateral rays.

Preservation.—All specimens are preserved in dolomite and, together with other organisms from this locality, are now molds.

Discussion.—This is the only ischaditid that possesses rays with angular walls. The shafts of laterals in mid-position of the young specimens are similar to the laterals of *I. abbottae*, which are gradually

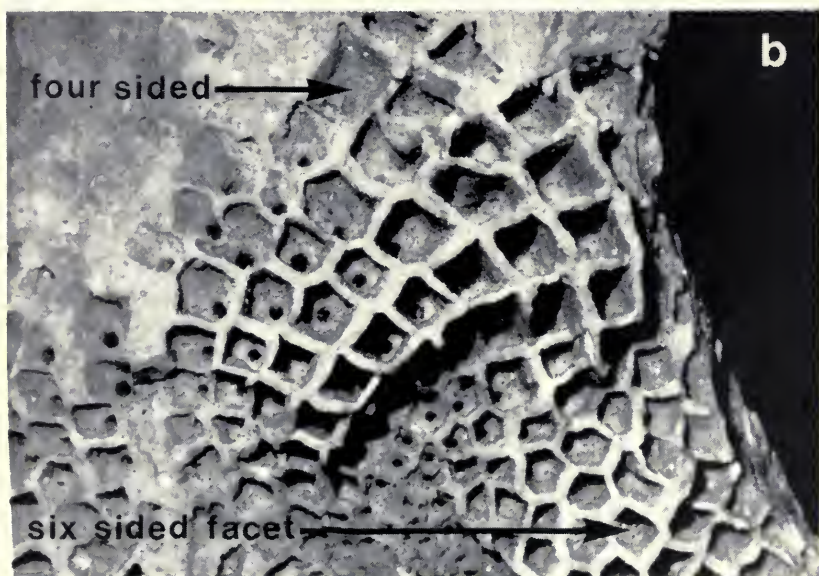
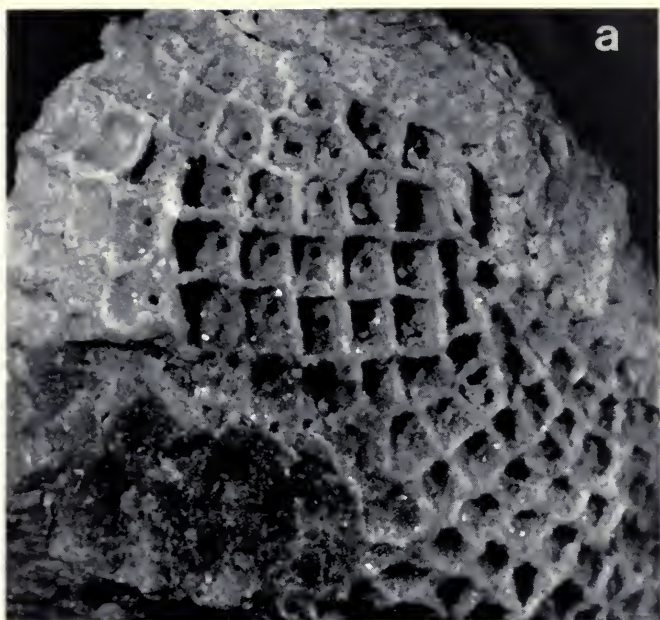


FIG. 43. Surface details of *Ischadites prismaticus*. Six- and four-sided facets are shown. a, FMNH PP 17720 ($\times 3.3$); b, holotype FMNH PP 17719. ($\times 3.2$)

expanding. In both species in young condition the main axis is pointed.

The presence of six-sided together with four-sided facets is similar to *I. hemisphericus*.

Stratigraphic position.—Top of reef in Racine Dolomite.

Locality.—Bridgeport Quarry, Chicago, Illinois and Waukesha, Wisconsin.

Holotype.—FMNH PP 17719.

Other material.—FMNH, USNM, UWM.

Ischadites ? sp.

Receptaculites sp. indet. Whiteaves, 1906, *Palaeoz. fossils*, **3**, part 4, p. 276.

Sphaerospongia tessellata Whiteaves, 1892, *Contr. Canad. Palaeontol.*, **1**, part 4, p. 259; Whiteaves, 1899, *Science*, n.s., **10**, p. 433.

Discussion.—Whiteaves (1892, 1899) identified a fragmentary fossil from Limestone Rapids of the Fawn branch of the Severn River [Northern Ontario] as *Sphaerospongia tessellata* Phillips. He considered it to be Devonian. However, later Whiteaves (1906) assigned the fossils because of its "square plates" to the genus *Receptaculites* and lowered its stratigraphic position to Silurian.

This fragmentary fossil has never been illustrated, its whereabouts is unknown and, therefore, its exact generic assignment cannot be made. However, since North American *Sphaerospongia* is probably *Ischadites*, and since Whiteaves confused his fossil fragment with *Sphaerospongia*, the fossil is tentatively assigned to *Ischadites*.

Stratigraphic position.—Severn River Limestone.

Locality.—Limestone Rapids of the Fawn River close to Severn River, Port Nelson Area, Ontario, Canada. Collected by A. P. Low in 1866.

Material.—The whereabouts of the fossils are unknown.

UNDETERMINED RECEPTACULITACEAE

Receptaculites ? sp.

Receptaculites Foerste, 1904, *Amer. Jour. Sci.*, ser. 4, **18**, no. 107, p. 341.

Discussion.—Foerste (1904) lists the *Receptaculites* as an Osgood fossil from Big Creek in Southern Indiana. No decision can be made on the taxonomic assignment of this fossil.

Stratigraphic position.—Osgood Formation.

Locality.—Big Creek [probably Jefferson County] Indiana.

Material.—Depository of the fossil unknown.

Receptaculites ? sp.

Receptaculites sp. Cumings and Shrock, 1928, Ind. Conserv. Comm. Publ. 75, pp. 97, 189.

Discussion.—Cumings and Shrock (1928) listed a *Receptaculites* sp. from the quarry at Ridgeville in Northern Indiana. Since no description or discussion of the fossil is available, no decision on its taxonomic placement can be made. The Ridgeville Quarry consists of 20 ft. of bedded dolomite above the massive reef rock (Cumings and Shrock, 1928). This part of the stratigraphic section has been referred to as Huntington Dolomite which was correlated with Guelph and Racine (Swartz, 1942). These two formations are equivalent to Racine Dolomite.

Stratigraphic position.—Huntington, Lithofacies of Wabash Formation (Pinsak and Shaver, 1964, p. 34).

Locality.—Quarry at Ridgeville, Randolph County, Indiana.

SPECIES ERRONEOUSLY CONSIDERED SILURIAN

Receptaculites biconstrictus Ulrich in Bassler, 1909.

"Receptaculites" sp. Rietschel, 1969, Senck. lethaea, **50**, pl. 2, fig. 7.

Discussion.—Rietschel (1969) illustrated a common North American Ordovician *Receptaculites biconstrictus* as *"Receptaculites"* sp. from Silurian, Niagaran? from Tennessee.

Stratigraphic position.—Ordovician.

Locality.—Tennessee.

Referred specimen.—BMNH P6518.

Receptaculites oweni Hall, 1861. Figures 44, 45.

Receptaculites pearyi Whitfield, 1900, Bull. Amer. Mus. Nat. Hist., **13**, pp. 19–20, pl. 1, figs. 1, 2; Whitfield and Hovey, 1900, Bull. Amer. Mus. Nat. Hist., **11**, p. 350; Bassler, 1915, Bull. U. S. Nat. Mus. **92**, **2**, p. 1098; Squires and Hawkins, 1958, Amer. Mus. Nat. Hist. Nov., no. 1913, p. 17.

Discussion.—Whitfield (1900, pp. 19–20) described as Niagaran, or Clinton, a new Arctic *Receptaculites pearyi*. The examination of this fossil indicates that it is, however, Ordovician in age, and does not differ from *Receptaculites oweni* Hall from the Arctic or from any other North American locality. It is assumed that Whitfield was

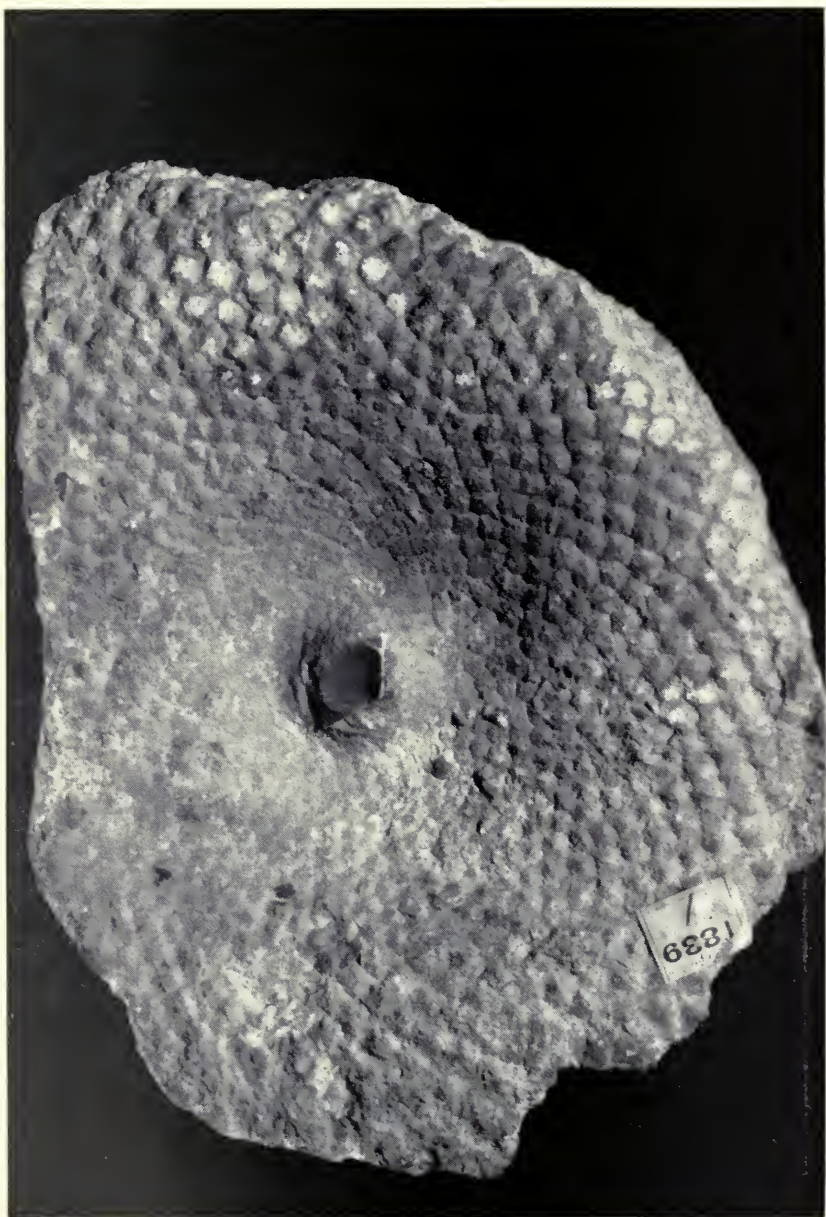


FIG. 44. Holotype of *Receptaculites pearyi* [= *R. oweni*]. AMNH 1831/1. ($\times 1.5$)



FIG. 45. Details of laterals of the holotype of *Receptaculites pearyi* [= *R. oweni*]. AMNH 1831/1. ($\times 2.7$)

mistaken in his stratigraphic assignment of this specimen. The fossils had been collected by Peary Expedition of 1898 and sent to the American Museum for examination. Whitfield in the same publication described also as new and as Silurian *Heliolites perelegans*. With this new species he illustrated a fragment of *R. pearyi*. The examination of the type specimens of *R. pearyi* (figs. 44, 45) and of the fragment associated with *Heliolites perelegans* indicates that these fossils are *R. oweni*. In addition, the list of fossils that Whitfield included with his new species further supports the Ordovician age. Thus *R. pearyi* is now considered a synonym of *R. oweni*.

Whitfield noticed the similarity of his fossil with the *R. oweni* and later had doubts about the stratigraphic position (Whitfield and Fovey, 1900, p. 350).

The proper taxonomic placement of *R. oweni* Hall, 1861 is in doubt. It appears now that *R. oweni* Hall, 1861 is identical with *R. occidentalis* Salter, 1851 (Nitecki, MS).

Stratigraphic position.—Ordovician.

Locality.—Cape Bay, Princess Marie Bay, Ellesmere Island, Northwest Territories, Canada.

"Holotype".—AMNH 1839/1

Referred specimen.—AMNH 1837/1.

REFERENCES

AMI, H. M.

1894. Notes on fossils from Quebec City, Canada. *Ottawa Nat.*, 8, pp. 82-90
(= *Trans. Ottawa Field-Naturalists' Club*, 10).

ANONYMOUS

1966. *British Palaeozoic fossils*, 2nd ed. *Brit. Mus. (Nat. Hist.)*, London. 208 pp., 69 pls.

BALL, JOHN R. and KATHERINE F. GREACEN

1946. Catalog of the Egan collection of Silurian invertebrate fossils at the Chicago Academy of Sciences. *Chgo. Acad. Sci., Spec. Pub.*, no. 7, 55 pp.

BASSLER, RAY S.

1915. Bibliographic index of American Ordovician and Silurian fossils. *Bull. U. S. Nat. Mus.* 92, 2 vols., 1,521 pp.

BERRY, W. B. N., A. J. BOUCOT, JEAN M. BERDAN, GILBERT KLAPPER, ANDERS MARTINSON, CARL B. REXROAD, RICHARD P. SHELDON, and ALFRED M. ZIEGLER

1970. Correlation of the North American Silurian rocks. *Geol. Soc. Amer. Spec. Paper* 102, 289 pp., 13 figs., 2 pls., 2 tables.

BIGSBY, JOHN J.

1868. *Thesaurus Siluricus*. The flora and fauna of the Silurian Period. With addenda (from recent acquisitions). John Van Voorst, London. 214 pp., 1 map.

BILLINGS, ELKANAH

1857. Report for the year 1856, of E. Billings, Esq., Palaeontologist, addressed to Sir William E. Logan, Provincial Geologist. *Geol. Surv. Canada. Report of Progress for 1853-54-55-56*, pp. 247-345.

1863. Catalogue of Lower Silurian fossils. *In* Logan, William E., *Geol. Survey Canada. Report of progress from its commencement to 1863*; illustrated by 498 wood cuts in the text, and accompanied by an atlas of maps and sections. 983 pp.

- 1865a. Palaeozoic fossils. Volume 1. Containing descriptions and figures of new or little known species of organic remains from the Silurian rocks. 1861-1865. *Geol. Surv. Canada*, 426 pp., 401 figs.

- 1865b. Notes on some of the more remarkable genera of Silurian and Devonian fossils. *Canad. Nat.*, new ser., 2, pp. 184-198, 14 text-figs.

1866. Catalogues of the Silurian fossils of the Island of Anticosti, with descriptions of some new genera and species. *Geol. Surv. Canada Spec. Rept.* 93 pp., numerous figs.

BOLTON, THOMAS E.

1966. Catalogue of type invertebrate fossils of the Geological Survey of Canada. *Geol. Surv. Canada, Dept. Mines and Technical Surveys*, Ottawa, Canada, 3, 203 pp.

BRETZ, J HARLEN

1939. Geology of the Chicago region. *Ill. State Geol. Surv. Bull.* 65, part 1, 118 pp., 7 pls., 91 text-figs.

BROWN, C. ERVIN and JESSE W. WHITLOW

1960. Geology of the Dubuque South Quadrangle Iowa-Illinois. U. S. Geol. Surv. Bull. 1123-A, 93 pp., 1 pl., 18 text-figs.

BYRNES, JOHN G.

1968. Notes on the nature and environmental significance of the Receptaculitaceae. *Lethaia*, **1**, pp. 368-381, 5 text-figs.

CALEY, J. F.

1940. Palaeozoic geology of the Toronto-Hamilton area, Ontario. Geol. Surv. Canada Mem. 224, 284 pp., 2 maps, numerous tables.

CALVIN, SAMUEL

- 1893a. On the structure and probable affinities of *Cerionites dactylioides* Owen. *Amer. Geol.*, **12**, pp. 53-57, 1 text-fig.
1893b. On the structure and probable affinities of *Cerionites dactylioides* Owen. *Proc. Iowa Acad. Sci.*, for 1892, **1**, part 3, pp. 13-15.
1898. Geology of Delaware County, pp. 119-199, 13 pls., 1 map. *In Iowa Geol. Survey*, **8**, Ann. Rept. for 1897.

CALVIN, SAMUEL and H. F. BAIN

1900. Geology of Dubuque County, pp. 379-651, text-figs. 45-102, pls. 4-11, 3 maps. *In Iowa Geol. Surv.*, **10**, Ann. Rept. for 1899.

CHAMBERLAIN, T. C.

1878. Geology of Eastern Wisconsin. *In Geology of Wisconsin. Survey of 1873-1877*, **2**, 2nd ed., part 2, pp. 93-405, pls. 2-13A, 48 text-figs.

CHINA, W. E.

1970. Opinion 909. *Receptaculites* Deshayes, 1828 (Receptaculitids): validated under the plenary powers. *Bull. Zool. Nomencl.*, **27**, part 1, pp. 14-15.

CLARKE, JOHN M.

1920. Seventeenth report of the director of the State Museum and Science Department. N. Y. State Mus. Bull. nos. 239, 240, 63 pp., 12 pls., 1 map.

CLARKE, JOHN M. and RUDOLPH RUEDEMANN

1903. Catalogue of type specimens of Paleozoic fossils in New York State Museum. N.Y. State Mus. Bull. 65. *Paleontol.*, **8**, 847 pp.

COLLINSON, C. W.

1959. Guide for beginning fossil hunters. Ill. State Geol. Surv., educ. ser., **4**, 39 pp., illus.

CUMINGS, EDGAR R. and ROBERT R. SHROCK

1928. The geology of the Silurian rocks of Northern Indiana. Indiana Dept. Conserv., Conserv. Commission. Publ. 75, Div. Geol., 226 pp., 78 text-figs.

CURRIE, ETHEL D. and WILFRED NORMAN EDWARDS

1943. Dasycladaceous algae from the Girvan area. *Quart. Jour. Geol. Soc. London*, **98**, pp. 235-240, pl. 11, 1 text-fig.

DEFRANCE, J. L. M.

1827. Réceptaculite, pp. 5-7, pl. 68. *In Dictionnaire des Sciences Naturelles*, **45**, Re-Rocher. Paris, France, 548 pp. and atlas.

DESHAYES, G. P.

1828. Réceptaculite. *In Dictionnaire classique d'histoire naturelle*, **14**, p. 486.

DOWLING, D. B.

1901. Report on the geology of the west shore and islands of Lake Winnipeg. Canada Geol. Surv. Ann. Rept., n. ser., **11**, for 1898. Rept. F, 100 pp., numerous figures.

DRESSER, JOHN A. and T. C. DENIS

1941. Geology of Quebec, **2**. Descriptive Geology, Quebec Bur. Mines Geol. Rept. **20**, 544 pp., 44 pls., 41 text-figs., 3 maps.

EGEROD, LOIS EUBANK

1952. An analysis of the Siphonous Chlorophycophyta. Univ. Calif. Publ. Botany, **25**, no. 5., pp. 325-454, pls. 29-42, 23 text-figs.

ELIAS, MAXIM K.

1947. *Permopora keenae*, a new Late Permian alga from Texas. Jour. Paleontol., **21**, no. 1, pp. 46-58, pl. 18, 8 text-figs.

ENDO, RIUJI

1932. The Canadian and Ordovician formations and fossils of South Manchuria. Bull. U. S. Nat. Mus. **164**, 152 pp., 40 pls.

ETHERIDGE, ROBERT

1888. Fossils of the British Islands stratigraphically and zoologically arranged. **1**, Palaeozoic, Clarendon Press, Oxford. 468 pp.

FAGERSTROM, J. A.

1961. The fauna of the Middle Devonian Formosa Reef Limestone of Southwestern Ontario. Jour. Paleontol., **35**, pp. 1-48, 14 pls., 1 text-fig.

FINKS, ROBERT M.

1960. Late Paleozoic sponge faunas of the Texas region. The siliceous sponges. Amer. Mus. Nat. Hist. Bull., **120**, art. 1, 160 pp., 50 pls., 77 text-figs.

FISHER, D. JEROME

1925. Geology and mineral resources of the Joliet Quadrangle. Bull. Ill. Geol. Surv. no. 51, 160 pp., 2 maps, 9 tables, 47 figures, 6 pls.

FOERSTE, AUG. F.

1904. The Ordovician-Silurian contact in the Ripley Island area of Southern Indiana, with notes on the age of the Cincinnati geanticline. Amer. Jour. Sci., ser. 4, **18**, no. 107, pp. 321-342, pl. 17, 1 text-fig.

1909. Preliminary notes on Cincinnati and Lexington fossils. Bull. Sci. Lab. Denison Univ., **14**, pp. 289-324, pls. 7-11.

1910. Preliminary notes on Cincinnati and Lexington fossils of Ohio, Indiana, Kentucky and Tennessee. Bull. Sci. Lab. Denison Univ., **16**, pp. 17-87, 6 pls.

1916. Notes on Cincinnati fossil types. Bull. Sci. Lab. Denison Univ., **18**, pp. 285-355, 7 pls.

1929. The Ordovician and Silurian of American Arctic and Subarctic regions. Bull. Sci. Lab. Denison Univ., **24**, pp. 27-79, pls. 2-3.

GABAU, AMADEUS W.

1916. Comparison of American and European Lower Ordovician Formations. Bull. Geol. Soc. Amer., **27**, pp. 555-622, 10 text-figs.

GABAU, AMADEUS W. and HERVEY W. SHIMER

1909. North American index fossils, Vol. 1. A. G. Seiler and Co., N.Y. 853 pp., 1,210 figs.

GREACEN, KATHERINE F. and JOHN R. BALL

1944. Studies of Silurian fossils in the Thomas A. Greene Collection at Milwaukee-Downer College. Trans. Wisc. Acad. Sci. Arts Letters, **36**, pp. 415-419.

1946. Silurian Invertebrate fossils from Illinois in the Thomas A. Greene Memorial Museum at Milwaukee-Downer College. Milwaukee-Downer College Bull., 61 pp.

GÜMBEL, C. W.

1876. Beiträge zur Kenntniss der Organization und systematischen Stellung von *Receptaculites*. Abh. bayer. Akad. Wiss., math-phys. cl., **12**, no. 1, pp. 167-215, table A.

HALL, JAMES

1861. Descriptions of new species of fossils; from the investigations of the Survey. In Report of the Superintendent of the Geological Survey [of Wisconsin], exhibiting the progress of the work, January 1, 1861, pp. 9-52.

1862. Palaeontology of Wisconsin. In Rept. Geol. Surv. State Wis., **1**, chap. 9, pp. 425-442.

1863a. Note on the geological range of the genus *Receptaculites* in American Palaeozoic strata. N.Y. State Cab. Nat. Hist., 16th Ann. Rept., Appendix D (Contributions to Palaeontology; principally from investigations made during the years 1861 and 1862), Article 4, pp. 67-69.

1863b. Art. XII. Notice of some new species of fossils from a locality of the Niagara group, in Indiana; with a list of identified species from the same place. Trans. Albany Inst., **4**, 34 pp. Advance sheets.

1864. Notice of some new species of fossils from a locality of the Niagara group, in Indiana; with a list of identified species from the same place. Trans. Albany Inst., **4**, Art. 12, pp. 195-228.

1867. Account of some new or little known species of fossils from rocks of the age of the Niagaran Group. 20th Ann. Rept. State Cab. Nat. Hist., pp. 305-401, 14 pls.

1870. Descriptions of new or little known species of fossils from rocks of the age of the Niagara group. 20th Ann. Rept. Regents of the Univ. State N. Y. on the Condition of the State Cabinet of Nat. Hist., (rev. ed.), pp. 347-438.

1871. Organic remains of the Niagara group and associated limestones. Geol. Surv. State Wisc., 1859-1863, Palaeontol., part third, 94 pp., pls. 1-25.

1879a. Description of new species of fossils from the Niagara Formation at Waldron, Indiana. Adv. Sheet, printed by J. Munsell, Albany, N. Y., 20 pp.

1879b. The fauna of the Niagara group, in Central Indiana. 28th Ann. Rept. New York State Mus. Nat. Hist. Regents Univ. State, New York. State Mus. ed., pp. 99-203, pls. 3-34, 6 text-figs.

1882. Descriptions of the species of fossils found in the Niagara group at Waldron, Indiana. Geol. Surv. Indiana. 11th Ann. Rept. State Geologist. Palaeontology, pp. 217-414, 36 pls.

1882 [1883]. Descriptions of new species of fossils from the Niagara Formation at Waldron, Indiana. Trans. Albany Inst., **10**, pp. 57-76, 1 text-fig.

1883. Paleontology, Van Cleve's fossil corals. Indiana Dept. Nat. Hist., 12th Ann. Rept. for 1882, pp. 239-270, pls. 1-27, 1 text-fig.

HALL, JAMES and R. P. WHITFIELD

1875. Descriptions of invertebrate fossils, mainly from the Silurian System. In Rept. Geol. Surv. Ohio, **2**, Geol. Palaeontol. part 2, Palaeontol. sect. 1, pp. 65-161, pls. 1-9, 13, 14. The entire book appeared in 1875 in the German edition.

HANSMAN, ROBERT H. and HAROLD W. SCOTT

1967. Catalog of Worthen type and figured specimens at the University of Illinois. Jour. Paleontol., **41**, no. 4, pp. 1,013-1,028.

HEAD, WILLIAM R.

1895. Palaeozoic sponges of North America. 11 pp. published by the author, Chicago, Illinois.

HINDE, GEORGE JENNINGS

1884. On the structure and affinities of the family of the Receptaculitidae, including therein the genera *Ischadites*, Murch. (*Tetragonis*, Eichw.); *Sphaerospongia*, Pengelly; *Acanthochonia*, gen. nov.; and *Receptaculites*, DeFrance. Quart. Jour. Geol. Soc. London, **40**, pp. 795-849, pls. 36-37.

1887. A monograph of the British fossil sponges. Palaeontographical Soc. London. Part 1, 92 pp., 8 pls.

1888. A monograph of the British fossil Sponges. Palaeontographical Soc. London. Part II, pp. 93-188, pl. 9.

HOLTEDAHL, OLAF

1920. On the Paleozoic series of Bear Island, especially on the Heclahook System. Norsk. Geol. Tidsskrift., **5**, part 2, pp. 121-148, pls. 12-15, 6 text-figs.

HOWELL, BENJAMIN F.

1943. New records of Receptaculitidae from the Mississippi Valley. Bull. Wagner Free Inst. Sci., **18**, no. 4, pp. 35-42, 1 pl.

HUCKE, KURT and EHRHARD VOIGT

1967. Einführung in die Geschiebeforschung (Sedimentärgeschiebe) 132 pp., 50 pls., 24 text-figs. Verlag Nederland, Geol. Veren. Oldenzaal. Holland.

INGELS, JEROME J. C.

1963. Geometry, paleontology, and petrography of Thornton reef complex, Silurian of Northeastern Illinois. Amer. Assn. Petrol. Geol. Bull., **47**, no. 3, pp. 405-440, 16 text-figs., 1 table.

JOHNSON, J. HARLAN

1943. Geologic importance of calcareous algae with annotated bibliography. Quart. Colo. School Mines, **38**, no. 1, 102 pp., 23 figs., 2 tables.

1946. Lime-secreting algae from the Pennsylvanian and Permian of Kansas. Bull. Geol. Soc. Amer., **57**, no. 12, pp. 1,067-1,120, 5 text-figs., 10 pls.

1951. An introduction to the study of organic limestones. Quart. Colo. School Mines, **46**, no. 2, 185 pp., 104 pls., 1 fig.

1952. Ordovician rock-building algae. Quart. Colo. School Mines, **47**, no. 2, pp. 29-56, 12 pls., 3 tables.

1954. An introduction to the study of rock-building algae and algal limestones. Quart. Colo. School Mines, **49**, no. 2, 117 pp., 10 tables, 62 plates.

1963. Pennsylvanian and Permian algae. Quart. Colo. School Mines, **58**, no. 3, XVIII + 211 pp., 2 text-figs., 81 pls., 12 tables.

JOHNSON, J. HARLAN and KENJI KONISHI

1959. A review of Silurian (Gotlandian) algae. Quart. Colo. School Mines, **54**, Pt. I, no. 1, 114 pp., 29 pls., 8 tables, 9 maps, 1 fig.

JONES, T. R.

1882. Catalogue of the fossil foraminifers in the collection of the British Museum (Natural History), Cromwell Road. S.W. Taylor and Francis, London. 100 pp.

KAYSER, EMANUEL

1875. Ueber die Billings'sche Gattung *Pasceolus* und ihre Verbreitung in paläozoischen Ablagerungen. Z. Deut. Geol. Gesell., 27, pp. 776-783, pl. 20.

KESLING, ROBERT V. and A. GRAHAM

1962. *Ischadites* is a dasycladacean alga. Jour. Paleontol., 36, no. 5, pp. 943-952, pls. 135, 136, 2 text-figs.

KINDLE, EDWARD M.

1898. A catalogue of the fossils of Indiana, accompanied by a bibliography of the literature relating to them. 22nd. Ann. Rept. Ind. Geol. Surv., pp. 407-514.

KORDE, K. B., ed.

1963. Tip Chlorophyta. Systematic part in Orlov, Y. A. ed., Osnovy Paleontologii. Vodorosli, Mohobraznye, Isilofitovye, Plaunovidnye, Chlenistostevelnnye, Paporotniki. Pp. 199-223, 60 text-figs.

LAMONT, ARCHIE

1947. Gala-Tarannon beds in the Pentland Hills, near Edinburgh. Geol. Mag., 84, no. 4, pp. 193-208.

LAROUSSE, PIERRE, ed.

1875. Grand Dictionnaire Universel du XIX^e siècle. 13, 1,563 pp., numerous text-figs.

LAUBENFELS, MAX WALKER DE

1955. Porifera. In R. C. Moore, ed., Treatise on Invertebrate Paleontology, Geol. Soc. Amer., Univ. of Kansas Press, pt. E, pp. 21-112, text-figs. 14-89.

LEHMAN, ULRICH

1964. Ein Receptaculites als Geschiebe. Sonderheft 14 der VFMG "Funde und Fundmöglichkeiten in Nieder-Deutschland" Heidelberg, pp. 84-87, 3 text-figs.

LESLEY, J. P.

1889. A dictionary of the fossils of Pennsylvania and neighbouring states named in the reports and catalogues of the survey. Penn. Geol. Surv. Rept. P4, 2, pp. 438-914, covers N-R, numerous figs.

LOWENSTAM, HEINZ A.

1957. Niagaran reefs in the Great Lakes area. Geol. Soc. Amer. Mem. 67, 2, pp. 215-248, 4 text-figs.

MEEK, F. B. and A. H. WORTHEN

1868. Part II. Palaeontology. Geol. Palaeontol., 3, Geol. Surv. Ill., pp. 291-574, 20 pls., numerous text-figs.

1870. Descriptions of new species and genera of fossils from the Palaeozoic rocks of the Western States. Proc. Acad. Nat. Sci. Phila., 22, pp. 22-56.

MIAGKOVA, E. I.

1965. Soanitidae, a new group of organisms. Paleontol. Jour., 1965, no. 3, pp. 16-22, 2 pls., 3 text-figs. [In Russian].

MILLER, S. A.

1874. Genus *Pasceolus* Billings. Cincinnati Quart. Jour. Sci., 1, pp. 4-7, text-figs. 1-3.

1877. The American Palaeozoic fossils. A catalogue of the genera and species, with names of authors, dates, places of publication, groups of rocks in which found, and the etymology and signification of the words, and an introduction devoted to the stratigraphical geology of the Palaeozoic rocks. Cincinnati, Ohio. 245 pp.

1883. The American Palaeozoic fossils; a catalogue of the genera and species, with names of authors, dates, places of publication, groups of rocks in which found and the etymology and signification of the words, and an introduction devoted to the stratigraphical geology of the Palaeozoic rocks, 2nd ed., January, 1883, pp. 241-334.

1889. North American Geology and Palaeontology for the use of amateurs, students, and scientists. Cincinnati, Ohio. 664 pp., 1,194 text-figs.

MILLER, S. A. and W. F. E. GURLEY

1896. New species of Paleozoic invertebrates from Illinois and other states. Bull. Ill. State Mus. Nat. Hist., 11, pp. 8-50, 5 pls.

MORNINGSTAR, HELEN

1924. Catalogue of the type fossils in the Geological Museum at the Ohio State University. Ohio Jour. Sci., 24, no. 1, pp. 31-64.

MÜLLER, ARNO HERMANN

1967. Zur Morphologie von *Receptaculites neptuni* (Miscellanea). Neue. Jahrb. Geol. Paläontol. Abh., 129, no. 3, pp. 231-239, pls. 28-30, 2 text-figs.

1968. Über *Receptaculites* (Miscellanea, Receptaculitida N.). Freiburger Forschungshefte. C221, pp. 5-13, pls. 2-8, text-figs. 6-7, 1 table.

MURCHISON, RODERICK IMPEY

1839. The Silurian system, founded on geological researches in the counties of Salop, Hereford, Radnor, and so forth. John Murray, London. xxxii + 768 pp., 37 pls., 112 text-figs.

1854. Siluria. The history of the oldest known rocks containing organic remains, with a brief sketch of the distribution of gold over the earth. John Murray, London. 523 pp., 37 pl., numerous text-figs.

1859. Siluria. The history of the oldest fossiliferous rocks and their foundations; with a brief sketch of the distribution of gold over the earth. John Murray, London. 3rd ed., 592 pp., 41 pls., numerous text-figs., sections, and maps.

1872. Siluria. A history of the oldest rocks in the British Isles and other countries. With sketches of the origin and distribution of native gold, and general succession of geological formations and changes of the Earth's surface. 5th. ed., John Murray, London. 566 pp., map, 200 figs.

NEAVE, SHEFFIELD AIREY, ed.

1940. Nomenclator Zoologicus, 4, 758 pp.

NICHOLSON, HENRY ALLEYNE and ROBERT ETHERIDGE, JR.

1878-1880. A monograph of the Silurian fossils of the Girvan District in Ayrshire with special reference to those contained in the "Gray collection." 3 parts in one vol., 11 text-figs., 24 pls., 1 table.

NICHOLSON, HENRY ALLEYNE and RICHARD LYDEKKER

1889. A manual of palaeontology for the use of students with a general introduction on the principles of palaeontology, Vol. 1, 885 pp., 812 figs.

NITECKI, MATTHEW H.

1965. Catalogue of type specimens in Chicago Natural History Museum. Porifera. Fieldiana: Geol., 13, no. 6, pp. 477-509.

1967a. Systematic position of receptaculitids. Abst. Geol. Soc. Amer. Ann. Mtg., pp. 165-166 [and 1968, Geol. Soc. Amer. Spec. Papers 115, pp. 165-166].

1967b. *Receptaculites* Deshayes, 1828 (Receptaculitids): Proposed validation under the plenary powers. Z.N. (S.) 1787. Bull. Zool. Nomencl., 24, (2), pp. 119-120.

- 1968a. On the nature of the holotype of *Nipterella paradoxica* (Billings). Fieldiana: Geol., 16, no. 11, pp. 289-295, 4 text-figs.
- 1968b. The nature and the systematic position of receptaculitids. Intern. Paleontol. Union, Prague, pp. 19-20.
- 1968c. Revision of North American cyclocrinids. Geol. Soc. Amer., North-Central Sec., Ann. Mtg., p. 35.
- 1969a. Nature and variations of *Ischadites koenigii* Murchison. Geol. Soc. Amer. Abst. with Programs for 1969. Part 6, pp. 33-34.
- 1969b. Redescription of *Ischadites koenigii* Murchison, 1839. Fieldiana: Geol., 16, no. 13, pp. 341-359, 15 text-figs., 1 table.
- 1969c. Surficial pattern of receptaculitids. Fieldiana: Geol., 16, no. 14, pp. 361-376, 11 text-figs.
- 1969d. Algal nature of calathiids. XI. Intern. Bot. Congr. Abstr. p. 159.
- 1970a. North American cyclocrinid algae. Fieldiana: Geol., 21, xiii + 182 pp., 53 text-figs., 8 pls.
- 1970b. Redescription of *Ischadites elrodi* (S. A. Miller, 1892), a Lower Devonian receptaculitid. Fieldiana: Geol., 20, no. 5, pp. 77-83, 3 text-figs.
- 1971a. *Ischadites abbottae*, a new North American Silurian species (Dasycladales). Phycologia 10, pp. 263-275, 15 text-figs.
- 1971b. Amphispongieae, a new tribe of Paleozoic dasycladaceous algae. Fieldiana: Geol., 23, no. 2, pp. 11-22, 3 text-figs.
- 1971c. Notes on the Devonian *Ischadites stellatus* (Fagerstrom, 1961). Fieldiana: Geol., 23, no. 3, pp. 23-30, 3 text-figs.

OSGOOD, RICHARD G., JR. and ALFRED G. FISCHER

1960. Structure and preservation of *Mastopora pyriformis*, an Ordovician dasycladaceous alga. Jour. Paleontol., 34, no. 5, pp. 896-902, pls. 117-118, 2 text-figs.

OWEN, DAVID DALE

1844. Report of a geological exploration of part of Iowa, Wisconsin, and Illinois, made under instructions from the secretary of the Treasury of the United States, in the autumn of the year 1839; with charts and illustrations. Washington Govt. print. off., 191 pp., plates and maps. U.S. 28th Cong., 1st sess., Senate doc. no. 407.

PAIGE, SIDNEY

1916. Silver City Folio New Mexico, U.S. Geol. Surv., Geol. Atlas, no. 199, 19 pp., 17 figs., 13 pls., 3 maps.

PARONA, CARLO FABRIZIO

1933. Le spugne della fauna permiana di Palazzo Adriano (Bacino del Sosio) in Sicilia. Mem. Soc. Geol. Italiana, 1, 58 pp., 7 text-figs., 12 pls.

PECK, JOSEPH H., JR. and HERDIS B. MCFARLAND

1954. Whitfield collection types at the University of California. Jour. Paleontol., 28, no. 3, pp. 297-309, pl. 29.

PIA, JULIUS

1927. Abteilung: Thallophyta. In Hirmer, Max. Handb. Paläbot., München, pp. 31-136, figs. 14-129.

PINSAK, ARTHUR P. and ROBERT H. SHAVER

1964. The Silurian formations of Northern Indiana. Ind. Dept. Conserv. Geol. Surv. Bull. 32, 87 pp., 2 pls., 6 text-figs., 6 tables.

PRIBYL, ALOIS

1944. Príspevek k poznani českých zastupců rodu *Ischadites* Murch. with the English summary; (Contribution to the knowledge of the Bohemian representatives of the genus *Ischadites* Murch.) Vestník Kralovské České Společnosti Nauk. Trida matematiprirod. for 1944, 12 pp., 1 pl., 1 text-fig.

QUENSTEDT, F. A.

- 1876-1878. Petrefactenkunde Deutschlands, Bd. V. Korallen (Schwämme), 612 pp., 28 folio plates.

RAUFF, HERMANN

1892. Untersuchungen über die Organisation und systematische Stellung der Receptaculitiden. Abh. bayr-Akad. Wiss., math-phys. Cl., 17, pp. 645-722, 7 pls., 12 text-figs. [also issued separately with pagination 1-78].

RAYMOND, PERCY E.

1916. The correlation of the Ordovician strata of the Baltic Basin with those of Eastern North America. Bull. Mus. Comp. Zool., 56, no. 3, pp. 177-286, 8 pls.

RIETSCHEL, SIEGFRIED

1969. Die Receptaculiten. Eine Studie zur Morphologie, Organisation, Ökologie und Überlieferung einer problematischen Fossil-Gruppe und die Deutung ihrer Stellung im System. Senck. Lethaea, 50, pp. 465-517, 4 pls., 14 text-figs.

ROEMER, FERD.

- 1876, 1880, 1897. Lethaea geognostica. 1 Theil. Lethaea palaeozoica. Text and Atlas. 324 pp., 61 text-figs., 62 pls.
1888. Ueber die Gattungen *Pasceolus* und *Cyclocrinus*. Neues Jahrb. Mineral. Geol. Palaeontol., Band 1 (1888), pp. 74-75.

ROY, S. K.

1941. The Upper Ordovician fauna of Frobisher Bay, Baffin Land. Field Mus. Nat. Hist., Geol. Mem., 2, 212 pp., 146 text-figs.

SALTER, J. W.

1851. Descriptions of a few of the above fossils. Pp. 173-177, pls. 8-10. In Murchison, R. I., "On the Silurian rocks of the South of Scotland." Quar. Jour. Geol. Soc. London, 7, pp. 139-178.
1873. A catalogue of the collection of Cambrian and Silurian fossils contained in the Geological Museum of the University of Cambridge, Cambridge Univ. Press. 204 pp., numerous text-figs.

SCHULZE, F. E., W. KÜKENTOHL, K. HEIDER, and R. HESSE

1935. Nomenclator Animalium generum et subgenerum. Preuss. Akad. Wiss. Berlin, 5, part 21, pp. 2,989-3,052.

SEWARD, A. C.

1965. Links with the past in the plant world. Reprint ed. New Delhi. 142 pp., 20 figs.

SHIMER, HERVEY W. and ROBERT R. SHROCK

1944. Index fossils of North America. John Wiley and Sons, New York. 837 pp., 303 pls.

SHROCK, ROBERT R. and W. H. TWENHOFEL

1939. Silurian fossils from Northern Newfoundland. Jour. Paleontol., 13, no. 3, pp. 241-266, pls. 27-30, 3 text-figs.

SQUIRES, DONALD F. and EDWARD J. HAWKINS

1958. Type specimens of invertebrate fossils in the collections of the Department of Geology and Paleontology, 1. Porifera. Amer. Mus. Nov., no. 1913, 22 pp.

STAUFFER, CLINTON R.

1915. The Devonian of Southwestern Ontario. Canada Geol. Surv. Mem. 34 (no. 63 Geol. Ser.), 341 pp., 20 pls., 1 map.

STOLLEY, E.

1896. Untersuchungen über *Coelosphaeridium*, *Cyclocrinus*, *Mastopora* und verwandte Genera des Silur. Archiv. Anthro. Geol. Schleswig-Holst. Benarch. Geb. 1, part 2, pp. 177-282, 105 text-figs. [also issued separately with different pagination].

SWARTZ, CHARLES K., (Chairman).

1942. Correlation of the Silurian Formations of North America. Bull. Geol. Soc. Amer., 53, pp. 533-538, 1 pl.

TEICHERT, CURT

1937. Ordovician and Silurian faunas from Arctic Canada. Rept. 5th Thule Exped. 1921-24. Danish Exped. Arctic North Amer., 1, no. 5, 169 pp., 24 pls.

TELLER, EDGAR E.

1911. A synopsis of the type specimens of fossils from the Palaeozoic formations of Wisconsin. Bull. Wisc. Nat. Hist. Soc., 9, no. 4, pp. 170-271.

THOMAS, A. O.

1923. Some new Paleozoic glass-sponges from Iowa. Proc. Iowa Acad. Sci., 1922, 29, pp. 85-88, 1 pl.

TOOMEY, DONALD F. and JEROME J. C. INGELS

1964. Reported Silurian occurrences of *Calathium* from the Thornton Reef, Illinois: a correction. Jour. Paleontol., 38, no. 6, pp. 1,102-1,104, pl. 171.

TWENHOFEL, W. H.

1914. The Anticosti Island Faunas. Geol. Surv. Canada, Mus. Bull. no. 3, Geol. ser. no. 19, 38 pp., 1 pl.
1928. Geology of Anticosti Island. Canada Geol. Surv. Memoir 154, 481 pp., 60 pls., 1 fig.
1938. A new species of *Receptaculites* (*R. pedunculatus*) from the Silurian strata of Eastern Wisconsin. Trans. Wisc. Acad. Sci., 31, pp. 545-546, 1 pl., 2 figs.

WALCOTT, CHARLES D.

1884. Paleontology of the Eureka district. U. S. Geol. Surv. Monograph, 8, 298 pp., 24 pls., tables.

WALTON, E. K.

1965. Lower Palaeozoic rocks—Stratigraphy. Pp. 161-220, 16 text-figs. In Craig, Gordon, Y., ed. The Geology of Scotland, Archon Books, Hamden, Conn.

WELLS, JOHN W.

1956. *Receptaculites* in the Upper Devonian of New York, Jour. Paleontol., 30, pp. 747-748, pl. 82, figs. 1, 2.

WHITEAVES, J. F.

1892. The fossils of the Devonian rocks of the islands, shores or immediate vicinity of Lakes Manitoba and Winnipegosis. Geol. Surv. Canada. Contr. Canad. Palaeontol., 1, part 4, pp. 251-359, pls. 33-47.

1897. The fossils of the Galena-Trenton and Black River formations of Lake Winnipeg and its vicinity. *Geol. Surv. Canada, Palaeozoic fossils*, 3, part 3, pp. 129-242, pls. 16-22.
1899. The Devonian System in Canada. II. *Science*, n.s. 10, no. 248, pp. 430-438.
1906. The fossils of the Silurian (Upper Silurian) rocks of Keewatin, Manitoba, the north eastern shore of Lake Winnipegosis, and the lower Saskatchewan River. *Geol. Surv. Canada. Palaeoz. fossils*, 3, part 4, pp. 243-298.

WHITFIELD, R. P.

- 1882a. Descriptions of new species of fossils from Ohio, with remarks on some of the geological formations in which they occur. *Ann. N. Y. Acad. Sci.*, 2, art. 13, pp. 193-244.
- 1882b. [1883] *Palaeontology*. In [Wisconsin Geol. Surv.] *Geology of Wisconsin*, 4, Survey of 1873-1879, part 3, pp. 161-363, 27 pls.
1883. Part II, chapter IV. *Hist. of Wisconsin fossils*, pp. 362-375. In *Geology of Wisconsin. Survey of 1873-1879*, 1, [Wisc. Geol. Surv.].
- 1890-91. Contributions to invertebrate palaeontology. *Ann. N. Y. Acad. Sci.*, vol. 5, pp. 505-568 (Dec. 1890), 569-600 (Jan. 1891), 601-620 (Feb. 1891) pls. 5-16, (1891).
1894. Contributions to the paleontology of Ohio, Chapter 3, pp. 407-494, 1 text-fig., 13 pls. In *Rept. Geol. Surv. Ohio*, 7, 700 pp., 56 pls., numerous text-figs.
1895. Republication of descriptions of fossils from the Hall collection in the American Museum of Natural History, from the report of progress for 1861 of the Geological Survey of Wisconsin, by James Hall, with illustrations from the original type specimens not heretofore figured. *Mem. Amer. Mus. Nat. Hist.*, 1, pt. 2, pp. 39-74, pls. 4-12.
1899. List of fossils, types and figured specimens, used in the palaeontological work of R. P. Whitfield, showing where they are probably to be found at the present time. *Ann. N. Y. Acad. Sci.*, 12, no. 8, pp. 139-186.
1900. Observations on and description of Arctic fossils. *Bull. Amer. Mus. Nat. Hist.*, 13, art. 2, pp. 19-22, pls. 1-2.

WHITFIELD, R. P. and EDMUND O. HOVEY

1899. Catalogue of the types and figured specimens in the palaeontological collection of the Geological Department, American Museum of Natural History. Part II. Beginning with the Medina Sandstone. *Bull. Amer. Mus. Nat. Hist.*, 11, pp. 73-188.

WILLIAMS, H.

1963. Twillingate Map—Area, Newfoundland. *Geol. Surv. Canada. Paper* 63-36, 30 pp., 1 table, 1 map.

WILLIAMS, M. Y.

1919. The Silurian geology and faunas of Ontario Peninsula, and Manitoulin and adjacent islands. *Geol. Surv. Canada. Mem.* 111, 195 pp., 34 pls. 6 text-figs. 2 maps.

WILSON, A. G.

1895. The Upper Silurian in Northeastern Iowa. *Amer. Geol.* 16, pp. 275-281.

WNCHELL, A. and O. MARCY

866. Enumeration of fossils collected in the Niagara Limestone at Chicago, Illinois; with descriptions of several new species. *Memoirs, Boston Soc. Nat. Hist.*, 1, pp. 81-113, pls. 2, 3.

WINCHELL, NEWTON H. and CHARLES SCHUCHERT

1895. Chapter III. Sponges, graptolites and corals from the Lower Silurian of Minnesota. *In* Geology of Minnesota, vol. 3, part 1, of the Final Report, Paleontology, Geol. Nat. Hist. Surv. Minnesota, pp. 55-95, pls. F and G., 7 text-figs.

WORTHEN, A. H. and F. B. MEEK

1875. Palaeontology of Illinois, section II. Description of invertebrates. Geol. Surv. Ill., 6, Geology and Palaeontology, pp. 489-532, pls. 23-33, 3 text-figs.

ZITTEL, KARL ALFRED

- 1877-1880. Studien über fossile Spongien. [This has been published in many parts under different titles in different journals over a period of years. Separates were issued with different pagination which were sometimes bound together in a volume with a new date. Translations and emendations were introduced. The most important of these parts are listed below].

- 1880 (1877-79). München, Akad. Abhandl., 13 (1 Abth.), pp. 1-63, 65-154; (2 Abth.), pp. 1-48.

- 1877a. Neus Jahrb. Mineral., pp. 337-378; 1878, *ibid*, pp. 561-618; 1879, *ibid*, pp. 1-40.

- 1877b. Ann. Mag. Nat. Hist. ser. 4 (transl. W. S. Dallas) 20, pp. 257-273, 405-425, 501-517; 1878, *ibid* ser. 5, 2, pp. 113-135, 235-247, 324-341, 385-394, 467-482; 1879, *ibid*, 3, pp. 304-312, 364-379; 1879, *ibid*, 4, pp. 61-73, 120-135.





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